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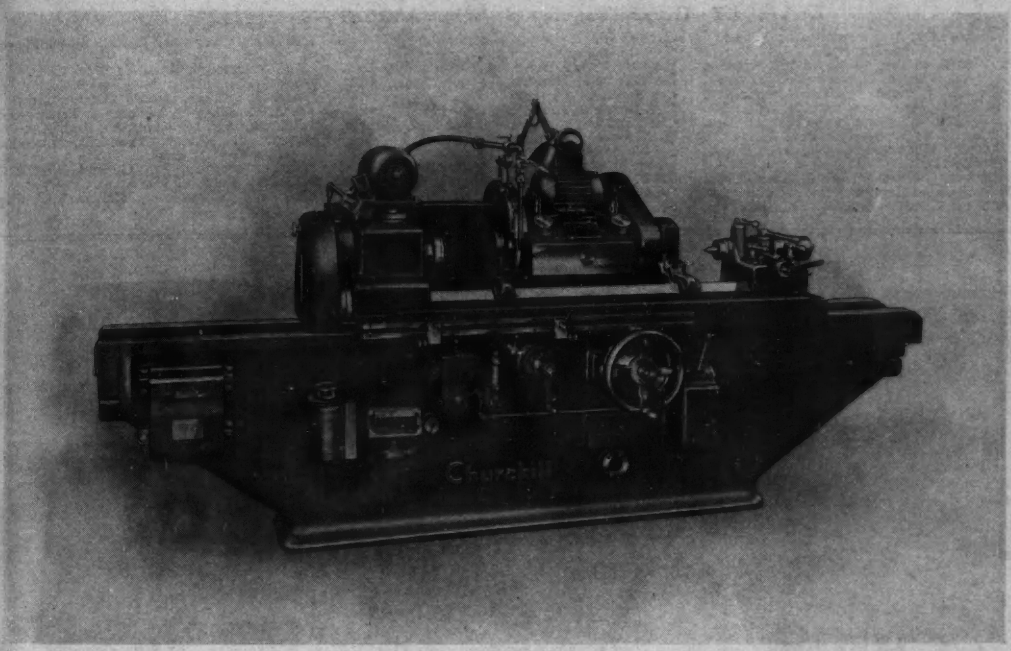

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NEW SKODA TURRET LATHES.

By J. GAIER. (From *Strojnicky Obzor*, Vol. 25, No. 8, April 20, 1945, pp. 125-135, 28 illustrations).

THE latest Skoda drum head turret lathes (Pitler type) produced at the time of publication of this article, were designed for using metal carbide tools for such operations as turning and cutting-off. But they are also suitable for operations for which high-speed steel is used such as drilling, reaming, and—in many cases—threading.

With carbide-tipped tools the machining times are very short. In order to effect economies on over-all production times, a reduction in auxiliary times should also be aimed at. The physical effort required of the operator should be kept to a minimum so that he can use the machine to its full capacity. The following features contribute to achieving this :

A three-speed reversible electric motor ; fine adjustment for automatic stopping of the transverse and longitudinal movements of the turret ; control of transverse and longitudinal automatic feed by one lever only ; engaging and disengaging of the clutch for transverse feed by a quick-acting lever.

The handwheel for slow transverse feed of the turret includes a friction clutch. Through this the transverse feed stop is always contacted under equal pressure making the disengagement of the feed independent of the operator's skill.

In this article the types R36, R47, and R60 are described which take bar-stock of 34, 45, and 58 mm. respectively. ($1\frac{3}{8}$, $1\frac{3}{4}$, and $2\frac{1}{4}$ ins.) Type R60 turret lathe is shown in Fig. 1.

The speed ranges of the main spindles of these three types are given in Table I. There are 5 series for R36, whereas R47 and R60 each have 7 series. The capacities of the lathes overlap, so that work down to a minimum of 30 mm. dia. ($1\frac{3}{16}$ in.) can also be done on R47, and R60 can take a minimum of 40 mm. dia. ($1\frac{9}{16}$ in.) The range of one speed series is 1 : 22·5 so that, on the same diameter, threads may be cut at 5 m/min. (16·5 ft./min.) and tipped tools may be employed at 120 m/min. (395 ft./min.) If no threading is to be done, the highest speed series may be selected giving a maximum speed of 330 m/min. (1085 ft./min.) on a 34 mm. dia. ($1\frac{1}{2}$ in.).

TABLE I. Speed ranges of Skoda turret lathes.

Speed series each having a range of 1 : 22·5		R36 r.p.m.	R47 r.p.m.	R60 r.p.m.
	I			18–400
	II		22–500	22–500
Each	III		28–630	28–630
series	IV		35–800	35–800
has	V		45–1000	45–1000
10	VI	56–1250	56–1250	56–1250
steps	VII	71–1600	71–1600	71–1600
	VIII	90–2000	90–2000	
	IX	125–2500		
	X	140–3150		
Total speed range		1 : 55	1 : 90	1 : 90

In each series 10 different speeds can be obtained by means of the three-speed motor and 4 pairs of sliding gears. (See Fig. 2.) The layout of the drive is simple and only one pair of sliding gears is meshing at any one time, so that the spindle runs very smoothly. Thus, the generation of heat is kept small and heat expansion of the head-stock, which would affect the precision of the work, is reduced to a minimum. For the same reason no friction clutch is used and the brake is situated outside the head-stock. The main spindle is of large diameter, held in front in a duplex adjustable roller bearing, and in the rear in preloaded ball bearings. The head-stock

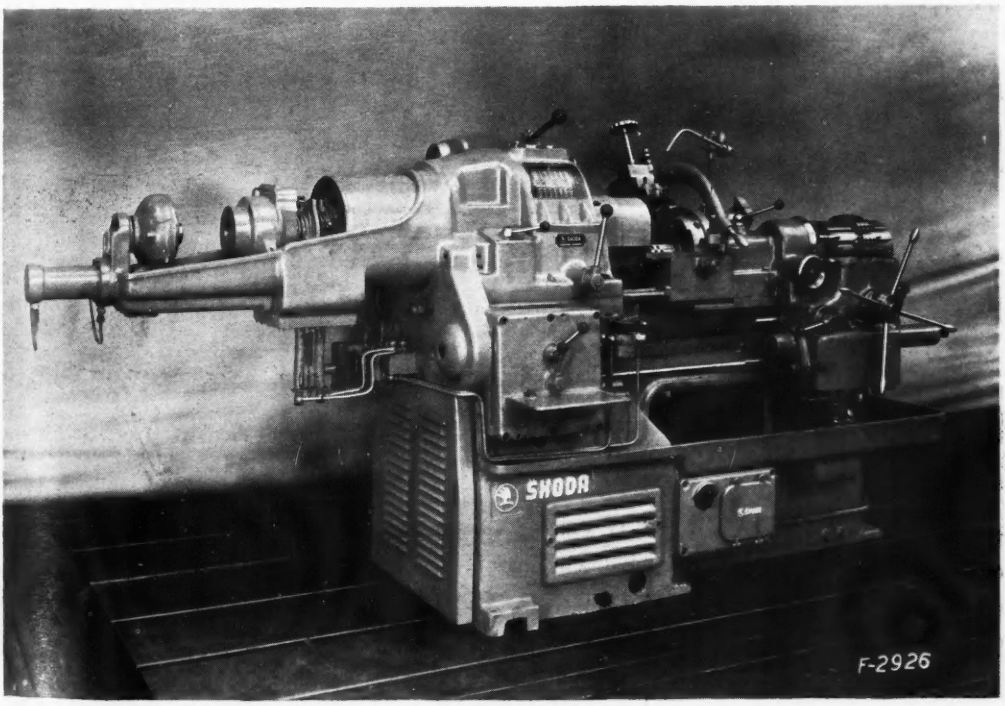


Fig. 1. **Latest Skoda turret lathe R60.** (1946 model).

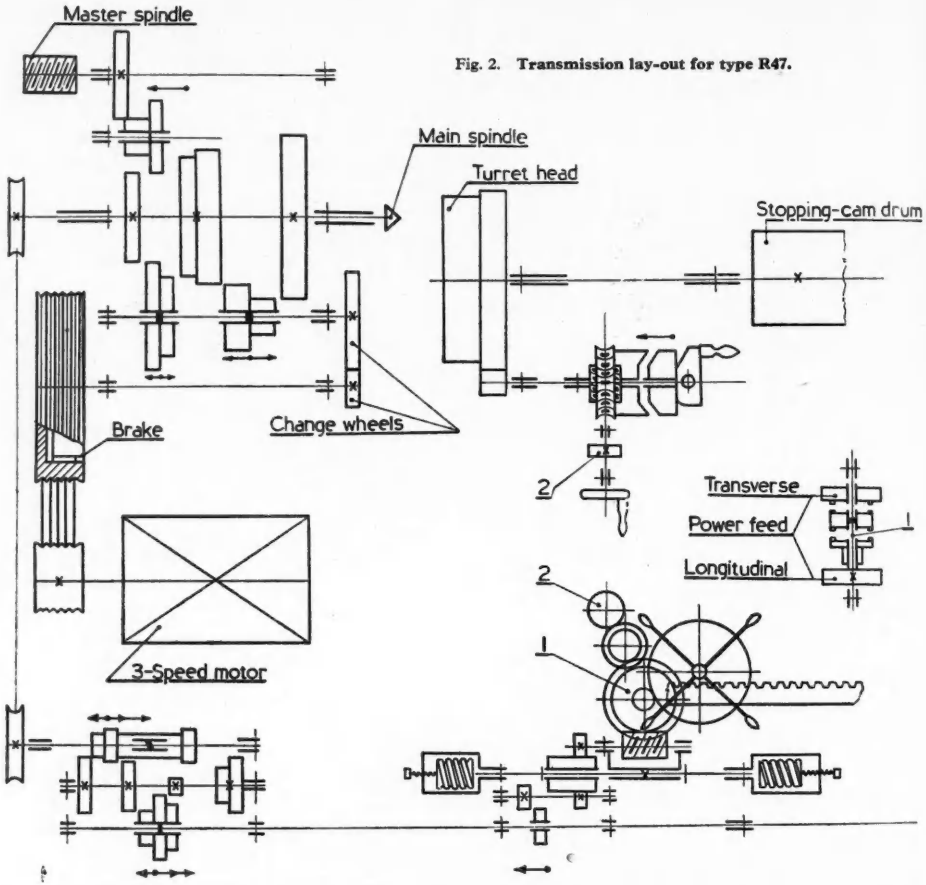


Fig. 2. **Transmission lay-out for type R47.**

has a wide base making the whole construction very rigid.

The electric motor is located inside the bed below the head-stock and the power is transmitted through V-belts. The spindle speeds are arranged in a geometrical progression with a ratio of 1·41. For many jobs it is sufficient only to change the motor speed (ratio 1 : 2 : 4) so that it is unnecessary to stop the machine to fit other sliding gears. Since machining times are reduced 35 to 75 per cent. (on an average of 50 per cent.) the power rating had to be increased by 100 per cent. When running at low speed the motor power is reduced, yet it is sufficient to do the job. The power ratings of the motors are given in Table II together with the maximum permissible short-time overloads.

TABLE II.—Power rating of electric motors.

Maximum dia. of bar-stock		Motor power in kW	
mm.	in.	rated	maximum permissible
36	1–7/16	5·5–4–2·6	9·5·7–3·5
47	1–7/8	8–6–3·5	13–8·6–4·7
60	1–3/8	10–5·7–4·3	15·7–10–5·7

FEED GEAR.

The feed gears are driven from the main spindle by means of a V-belt. Sliding gears in a closed gear box, controlled by two hand levers, provide for 6 or 9 different speeds. Longitudinal and transverse feed ranges are given in Table III. Lubrication is of the splash type.

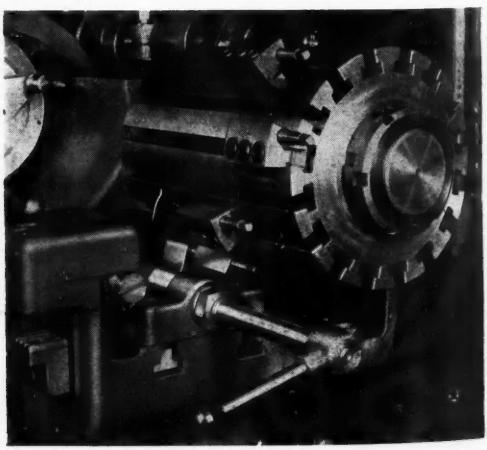


Fig. 3. **Feed stop in the bed and stopping-cam drum at the rear of the turret.**

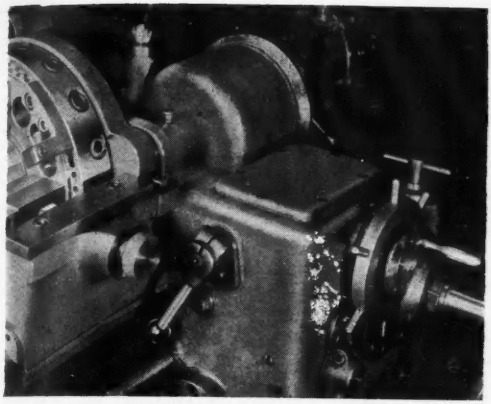


Fig. 4. **Micrometer transverse stop and transverse feed handwheel.**

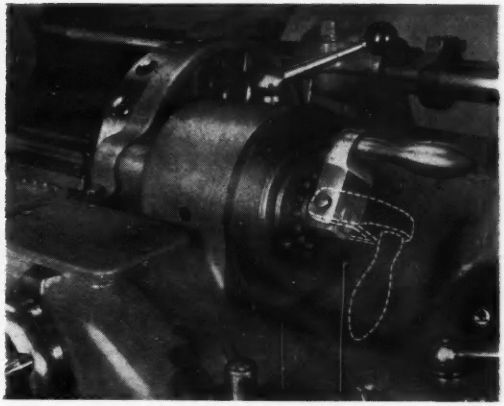


Fig. 5. **Transverse feed handle.**

TABLE III.—Feed rates of Skoda turret lathes.

Type	Longitudinal feed.		Transverse feed.	
	mm/rev.	1/1000 in/rev.	mm/rev.	1/1000 in/rev.
R36	0·056–0·56	2·2–22	0·028–0·28	1·1–11
R47	0·056–0·90	2·2–35	0·028–0·45	1·1–18
R60	0·056–0·90	2·2–35	0·028–0·45	1·1–18

THE TURRET.

A splined shaft transmits the feed from the headstock to the turret slide (apron) gear-box, which contains gears for both the transverse and longitudinal feed. Lubrication, by hand pump, is perfect and all the controls are within the operator's reach.

The longitudinal power traverse is automatically tripped by adjustable stops. They are arranged on a large drum at the rear of the turret. A multiple-stop drum is also provided as well as a simple removable stop at the front of the bed between the slide and the headstock. Tripping of the feed is effected within about 0·02 mm. (0·0008 in.). Before coming to a stand-still, the slide, during a few revolutions of the main spindle, is pressed against the stop by force. This force is adjustable up to a limit set by the maximum power rating of the respective motor. Cutting-off is done accurately and the surface is given a good finish.

The transverse automatic feed is tripped by the contact of adjustable cams with a stop located at the base of the turret slide. These cams also serve as supports when finishing cylindrical surfaces. A micrometer transverse stop, Fig. 4, together with the slow-motion transverse-feed handwheel and its friction clutch is most useful for precision finishing jobs. The feed tripping device also acts as a safety clutch against overloading.

Selection of transverse and longitudinal feed is controlled by one lever, so that both feeds cannot be engaged at the same time. In type R36, this lever also engages and disengages the feed. For transverse automatic feed, the friction clutch must also be engaged. This is done by lowering the quick transverse feed handle. (Fig. 5).

THE BED.

In all three types, cooling fluid tank, pump, and chip tray are incorporated in the beds. The guiding surfaces of the bed are flat and the turret slides are equipped with adjustable strips.

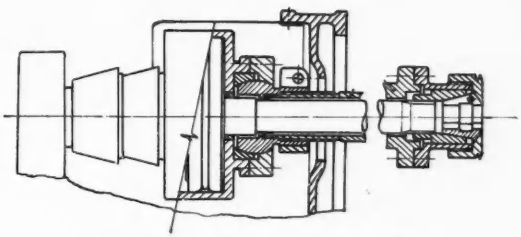


Fig. 6. **Chucking cylinder and chuck.**

OTHER FEATURES.

Compressed Air. Chucking of the work-piece and feeding-in of bar-stock is done by means of compressed air. These operations are controlled by a single lever or, alternatively, by a pedal. They are devices which

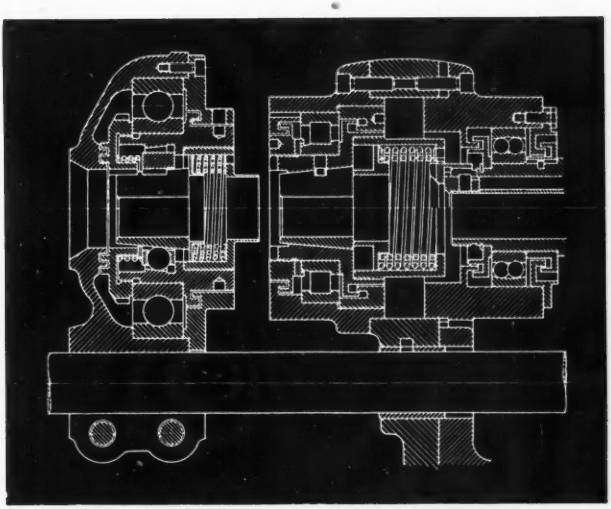


Fig. 8. **Feeding device for bar-stock.**

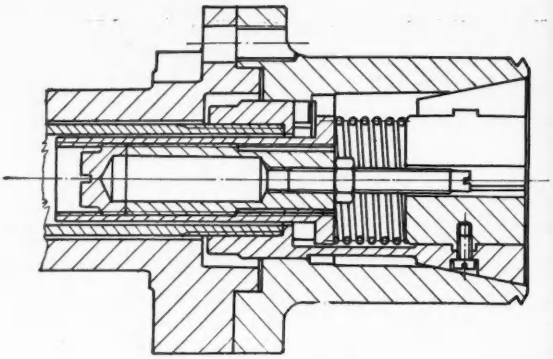


Fig. 7. **Chuck for single piece s.**

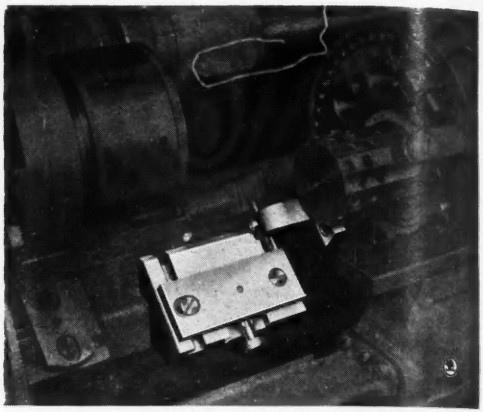


Fig. 11. **Longitudinal adjustable template.**

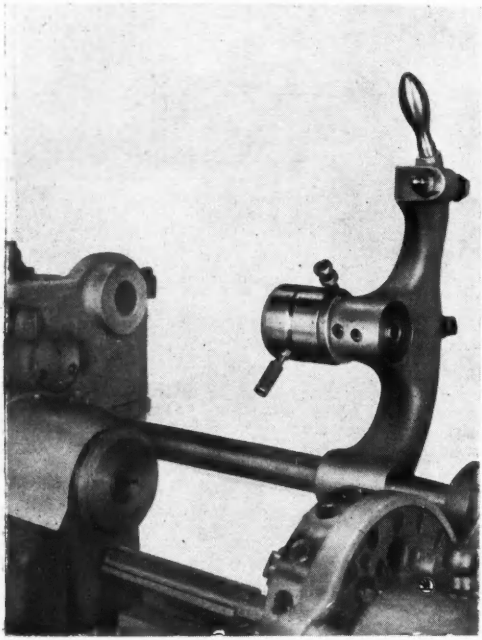


Fig. 9. **Arm for thread cutters.**

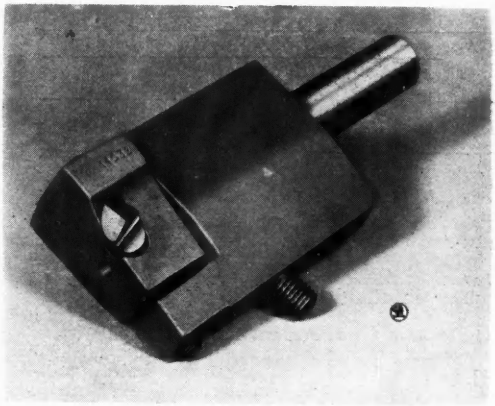


Fig. 12. **Simple tool holder with fine adjustment.**

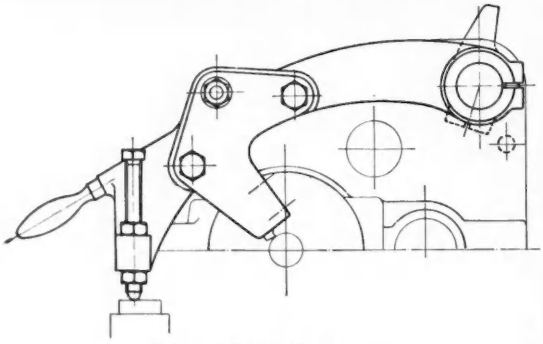


Fig. 10. **Cutting-in device.**

considerably reduce auxiliary times when compared with the usual equipment. Fig. 6 shows the chucking cylinder and chuck, Fig. 7, the chuck for single pieces. 3-jaw and 2-jaw universal chucks are also supplied. Fig. 8 indicates the design of the feeding device for bar-stock, which can handle stock within $\pm$ 1 mm. (0·04 in.) of the nominal diameter.

The air compressor is an independent, automatically controlled unit, delivering air at 7 atmos. (100 lb./sq. in.), 6 atmos. (85 lb./sq. in.) being required for the various chucking and feeding devices.

Special Accessories. A number of special accessories have also been developed. Fig. 9 shows the holder for thread chasers and taps. For these operations a master screw and nut are used.

An attachment for recessing or knurling tools is fixed close to the head-stock (Fig. 10) allowing such operations to be completed while the turret tools perform other work. Form and taper turning can be done by means of adjustable templates fixed to the bed (see Fig. 11).

TOOLS.

New strong tools and tool-holders were designed. One of the points to receive attention was to permit full length drills to be used without difficulty. The extended turret shaft can be used as a support for the tool-holders. Fig. 12 gives an example of a newly designed tool. The diameter of the tool holes in the turret has been made larger than in previous designs.

RECENT EXPERIENCES WITH AXIAL-FLOW BLOWERS.

By B. ECKERT. (From *VDI—Zeitschrift*, Vol. 88, No.37/38, September, 16, 1944, pp. 516-520, 11 illustrations.)

THE INCREASE OF STAGE PRESSURE.

IN contradistinction to the centrifugal type blower, the air flow in the axial-flow type does not experience a change of peripheral velocity u ; consequently there is no static pressure rise due to centrifugal force in the fan. The pressure head ΔH [m] or the total pressure rise Δp_{tot} [kg/m²], expressed by the dimensionless pressure coefficient

$$\psi = \frac{2g\Delta H}{u^2} = \frac{\Delta p_{tot}}{\frac{\rho}{2} u^2}$$

is smaller in the axial-flow type fan than in the centrifugal type ; ρ [kg sec²/m⁴] is the specific mass of the flow medium, g [m/sec²] the acceleration due to gravity, and u [m/sec] is the peripheral velocity of the blade tip.* Considerations of small weight and space necessitate an increase in stage pressures. The possibility to achieve this by an increase in r.p.m. is limited as with the increase of speed the noise also increases, and because, with the relative velocity approaching the speed of sound, the compressibility of the air becomes of more and more influence. The blade sections are aerofoil sections, and the blade and aircraft wing act in the same way. Thus the compressibility effect results at the beginning in increasing, and later on in decreasing the lift coefficient c_a, whilst the *Mach* number—i.e. the ratio of the speed of flow to the speed of sound,—and simultaneously the drag coefficient further increase. In other words the drag/lift ratio, $\epsilon = c_w/c_a$ influencing efficiency, becomes worse.

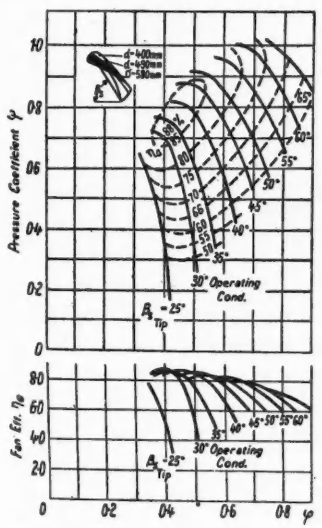


Fig. 1. **Characteristic of high pressure axial-flow fan.**
β_s stagger measured from chord of blade section.

Numerous tests† conducted under the aegis of the German Ministry of Transport have proved that a strong camber of the blade sections increases the lift coefficient and thereby also the pressure coefficient. Fig. 1 shows the performance curves of a single-stage axial-flow fan with blade sections of considerable camber. Pressure coefficient ψ and fan efficiency η_G are plotted against the dimensionless factor

$$\varphi = \frac{c_m}{u} = \frac{V}{Fu},$$

where c_m [m/sec] is the axial component of the absolute speed of flow c, V[m³/sec] the volume flow, and F the fan discharge area. It is possible to obtain, in a single stage fan for air under Standard Atmosphere conditions, a pressure rise of 0·5 to 0·6 kg/cm². To achieve best efficiencies at such pressures, the Reynolds number, based on mean relative inlet speed and length of chord of the blade section at the outer diameter, must not be less than 100,000.

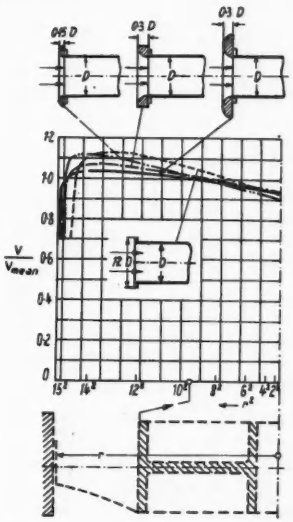


Fig. 2. **Influence of shape of intake nozzles on velocity distribution in front of axial-flow fan, plotted over the fan radii.**
v local (measured) velocity, v_m mean velocity. The velocities were measured immediately behind the intake nozzle.

DESIGN CONSIDERATIONS.

The Intake Duct.

To avoid fan inlet losses an intake nozzle should be provided. The velocity distribution in front of the fan depends on the aerodynamic quality of the intake nozzle. Tests without and with different intake nozzles lead to curves reproduced in Fig. 2, and show that without intake nozzle the velocity distribution is less uniform than with a correctly shaped intake nozzle. Foreign investigations show that it is possible with intake nozzles to increase ψ by 10 to 20 per cent and the fan efficiency by 10 to 15 per cent. (Fig. 3).

* It should be noted that it is German usage to give the quantity $\Delta H = \frac{p_1 - p_0}{\gamma} = \frac{\Delta p_{tot}}{\gamma}$ and not the pressure ratio p_1/p_0. The pressure head ΔH is given in metres of air column; $\gamma = \rho g$ is the weight of air per unit volume.—EDITOR, ENGINEERS' DIGEST.

† See by the same author, *Engine Cooling Problems arising in Motor Car Design*, Part II, THE ENGINEERS' DIGEST, Vol. IV, 1943, pp. 210-215.

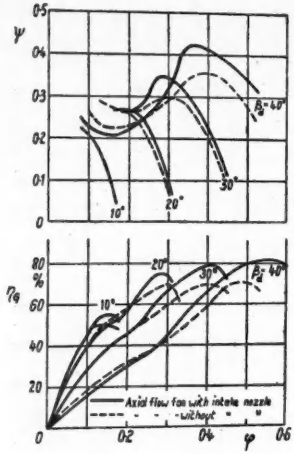


Fig. 3.
The improvement of fan characteristic due to intake nozzle.
β_d blade angle on pressure side.

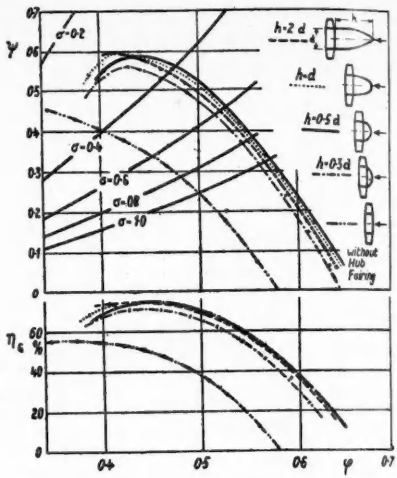


Fig. 4.
The effect of hub fairing on intake side.

Effect of Hub Fairing on Intake Side.

The increase of the pressure coefficient presupposes an increase of the hub ratio $\nu = d/D$; d = hub diameter, D = outer diameter of rotor. The shape of the hub fairing on the intake side affects the fan performance curves and the fan efficiency. As results shown in Fig. 4 indicate, the fairing of the hub results in an improvement under all operating conditions. The most favourable of the four shapes under investigation appears to be the semi-spherical fairing, as with this shape the sum of break-away and friction losses probably is at a minimum. The curves of σ in the figure represent ratios of dynamic pressure head of flow to total pressure rise

$$\sigma = \frac{\frac{\rho}{2} c_m^2}{\Delta p_{tot}} = \frac{\varphi^2}{\psi}.$$

σ is termed the " throttle coefficient."

Effect of Hub Shape at Discharge End.

With c_m [m/sec], the axial component of the absolute speed, and v [m/sec] the local speed, the total pressure rise is,

$$\Delta p_{tot} = \sum \frac{\rho}{2} v^2 \zeta + \frac{\rho}{2} . c^2_{m_1} - \Delta p_{stat} \text{ [kg/m}^2\text{]}.$$

Herein, the first member represents the pressure required to overcome all duct losses characterized by a coefficient of resistence ζ. $\frac{\rho}{2} c^2_{m_1}$ is the kinetic energy imparted to the air, and Δp_{stat}, the static energy which could be regained in a diffuser.

Introducing an ideal over-all efficiency of the diffuser

$$\eta_{1d} = \frac{\frac{\rho}{2} (c^2_{m_1} - c^2_{m_2})}{\frac{\rho}{2} c^2_{m_1}},$$

where c_{m_2} [m/sec] is the discharge velocity from the diffuser at the entry into the pipe line, the required total pressure rise can be expressed as

$$\Delta p_{tot\,1d} = \sum \frac{\rho}{2} v^2 \zeta + \frac{\rho}{2} c^2_{m_1} (1 - \eta_{1d}).$$

Taking into account the internal efficiency η_D of the diffuser, we have

$$\Delta p_{tot} = \sum \frac{\rho}{2} v^2 \zeta + \frac{\rho}{2} c^2_{m_1} (1 - \eta_{1d}\, \eta_D).$$

As the ideal total efficiency of the diffuser is governed by its dimensions only, a simple consideration as to the most efficient type of diffuser can be made in comparing the three basic types (Fig. 5), namely :

(a) Diffuser with increasing outer diameter and constant hub diameter,
(b) Diffuser with increasing outer diameter and increasing hub diameter,
(c) Diffuser with constant outer diameter and decreasing hub diameter.

These three types have been tested with different angles as shown in Fig. 5, where the diffuser efficiencies η_{1d} are plotted against the hub ratio ν. Designs of $\nu > 0{\cdot}5$ appear to be promising.

Tests are in progress in order to determine the internal efficiency η_D of the diffuser. For type (c)

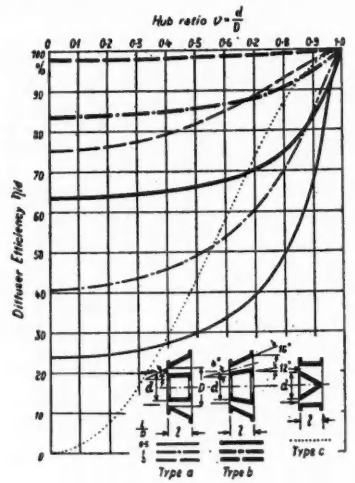


Fig. 5. **Ideal diffuser efficiency as a function of hub ratio for different types of diffusers.**

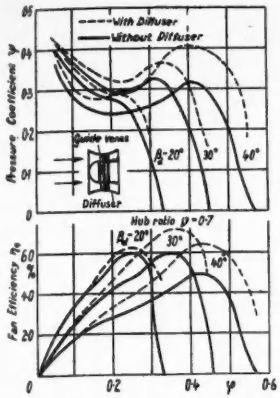


Fig. 6.
Fan characteristic and efficiency with and without diffuser.
β_d blade angle on pressure side

K. Wendt* has proved that η_D is about 88 to 89 per cent. Similar results can be expected for types (a) and (b).

The improvements which are due to a diffuser are illustrated in Fig. 6, where ψ and η_G are shown for a fan without and with diffuser.

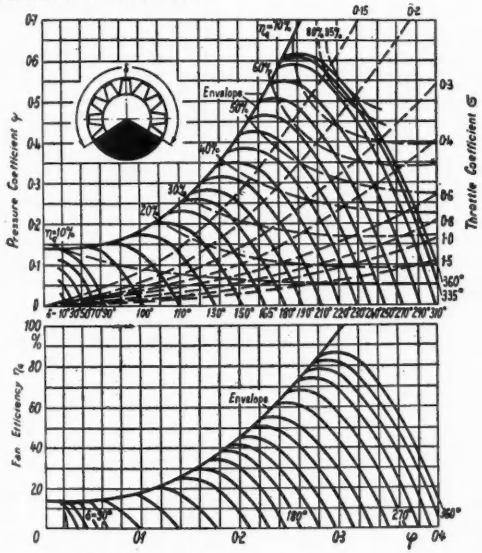


Fig. 7. **The effect of partial admission.**

The Effect of Partial Admission on Performance and Efficiency.

Often design features such as bearing consoles or other obstructions, especially in the case of cooling fans for motor cars, etc., allow of partial admission only, whereby the fan characteristic curve is changed. Tests have been made where a sector of the fan was blanked off as shown in Fig. 7 ; the admission angle varied between 10 deg. and 360 deg.

These tests show clearly the decrease of performance as expressed by the pressure coefficient ψ, and the decrease of φ and η_G with diminishing admission.

Under certain conditions, an intended partial admission can improve fan performances. This is the case

*Energieumsetzungen bei Naben-Diffusoren. Diploma dissertation at the Technical College, Hannover, 1937.

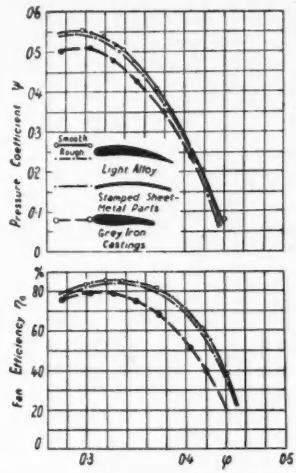


Fig. 8.
The influence of blade section and surface roughness.

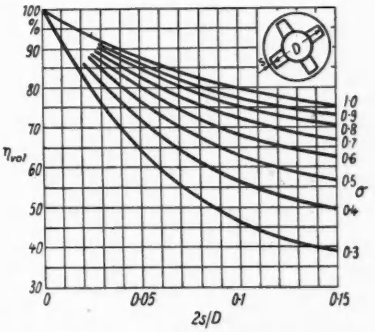


Fig. 9. **The influence of radial clearances on volumetric efficiency.**

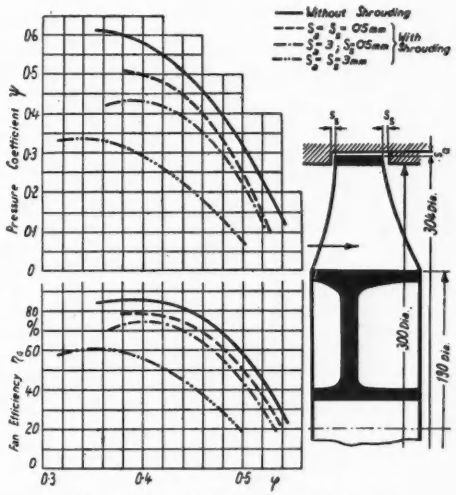


Fig. 10. **The effect of radial clearance S_R and axial clearance S_S on characteristic and efficiency of axial-flow fans with and without shrouding.**

if the duty point at full admission comes to lie on the unstable part of the characteristic. For this reason, in the light of present-day experience, the throttle coefficient $\sigma = \varphi^2/\psi = 0{\cdot}1$ should be the lowest value possible.

The Influence of Blade Section, Shape, and Surface Roughness.

For fans of greater output, the shape of the blade section is of great importance. The aerodynamically correct shape, however, requires expensive milling operations from the full material and therefore,—for certain purposes, at any rate,—it is more economical to manufacture the blade by welding of stamped sheet metal parts. Fig. 8 shows the characteristic curve for these two sections as applied to a 12-blade axial flow fan ; the differences are but small. The third section of grey iron casting shows a greater decrease of the pressure coefficient and efficiency due to the blunter discharge edge necessitated by the method of manufacture.

For fans of high quality the degree of surface roughness is also of great importance, the more so the higher the Reynolds number. The latter, based on the mean relative inlet velocity and the blade width at the outer diameter, was 325,000 for the aforementioned tests. The test points denoted " rough " were obtained on the light-alloy blade after first machining ; the height of excrescences was $^1/_{10}$ mm. After grinding of the blade the surface quality " smooth " was obtained. The blade of grey iron casting has also the attribute of " smooth ".

Volumetric Efficiency.

In connection with the tolerances to be obtained in manufacture of axial-flow fans, the question of the influence of radial clearance on fan performance often arises. Tests have so far indicated that a relationship (shown in Fig. 9), can be established and expressed by the empirical formula :

$$\eta_{vol} = e^{\frac{-2s/D}{\sigma}\,[3{\cdot}1-8{\cdot}1\,(2s/D)]}$$

where e is the base of Napier's logarithm, s the clearance and D the fan diameter.

To fit shrouding, as it is customary with steam turbine rotors, makes for higher strength, but in spite of a certain amount of labyrinth gland effect there is no improvement in the volumetric efficiency (Fig. 10).

FRANCE

BLOOM FORMATION OF IRON AND STEEL AND ITS RELATION TO CAPILLARITY AND DIFFUSION.

By E. EYT. (From *Fonderie*, No. 2, February 1946, pp. 53-61, 5 illustrations).

EVERY foundryman has been interested in the variety and mobility of the bloom, formed on the surface of molten iron and steel and in its growth into a continuous film. Its relationship to diffusion and capillarity phenomena has been investigated by Portevin and Bastien[1]).

I. THE CONDITIONS UNDER WHICH THIS FILM IS FORMED AND ITS CHARACTERISTICS.

The length of time, δ seconds, between the metal leaving the furnace and the formation of a continuous film depends upon the chemical composition and the initial temperature of the metal. δ increases almost directly with the carbon content. For an intitial temperature of 1650 deg. C.

$$\delta = 45C + 60 \quad .. \quad .. \quad (1)$$

where C is the carbon content in per cent. δ also increases, though less quickly, with manganese content and decreases equally quickly as chrome and tungsten contents increase. For Chromium, the variation is almost proportional to the log of the content.

$$\Delta\delta = A \log Cr \quad .. \quad .. \quad (2)$$

$\Delta\delta$ is the variation in the period of film formation, Cr the percentage of Chromium, A is a constant, being 65 up to 6 and 55 above 6 per cent chromium.

With silicon the variation is very complex, as shown by the full line in Fig. 1.

The noble metals, nickel, cobalt, and copper do not affect the time required for the film to form but oxidization reduces it very quickly, especially in the presence of oxidizing elements.

The temperature of film formation, (Θ) is constant for a given metal, depending on its chemical composition. The period of time for the film to form (δ) is the time required to cool down from initial bath temperature T_0 to Θ ; therefore, if V is the mean rate of cooling,

$$\delta = \frac{T_0 - \Theta}{V} \quad .. \quad (3) \quad \text{and} \quad \Delta\delta = -\frac{1}{V}\,\Delta\Theta \quad .. \quad (4)$$

From equation (4) it is seen that the curves for $\Delta\delta$ and $\Delta\Theta$ must be nearly symmetrical about the abscissa. This is shown in Fig. 1 where the dotted curve represents $\Delta\Theta$.

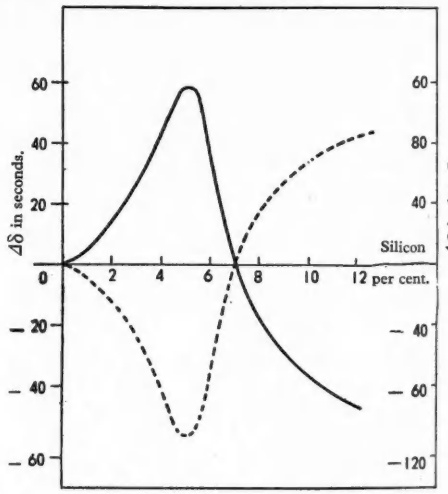


Fig. 1. Effect of silicon content on time and temperature of film formation.

Fig. 2 shows the variation of the temperature of film formation with carbon content, the time required for the film to form increases with the temperature of the metal and this fact is used in steelmaking to ascertain this temperature, but δ also depends on the rate of cooling V which is governed by a number of factors, such as mass of metal, shape, thickness, and nature of the refractory lining. δ therefore depends largely on the test conditions.

The appearance of the film and its radiant and reflecting properties would suggest that it consists of a non-metallic substance and this is confirmed by chemical analysis (see Table I). The *FeO* content is almost constant and much larger than needed to maintain equilibrium ; this is only possible owing to surface phenomena. The silica content varies with the silicon to the formula

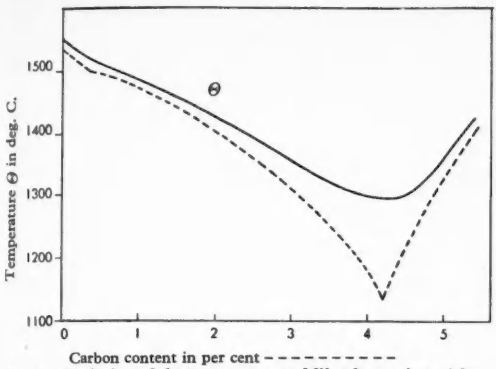


Fig. 2. **Variation of the temperature of film formation with carbon content.**

$$Si + 2\ FeO \leftrightharpoons SiO_2 + 2\ Fe$$

FeO being constant.

But the most curious fact which could not be anticipated, is the variation of composition with initial temperature. The thickness of the film has been measured by indirect method. The emissive power of an oxide layer is normal when its thickness exceeds 500 mμ. Assuming that the emissive power is proportional to the thickness, film thicknesses of 40 to 100 mμ have been calculated, showing that it is purely a surface film.

Many factors affect the film formation ; affinity of the elements for oxygen, physical state of the oxides formed, their melting point, chemical function etc. But three factors are preponderant, absorption of oxygen by the surface, diffusion, and surface phenomena.

TABLE I.

Metal characteristics		Film characteristics		
Silicon content per cent.	Initial temperature deg. C.	Silica content per cent.	*FeO* content per cent.	Temperature of formation deg. C.
0·4	1650	15	52	1360
0·4	1450	8	54	1320
0·6	1450	14	50	1330
1·1	1350	10	50	1300
1·6	1450	32	47	1390

II. DIRECT APPLICATIONS.

Temperature. In steelworks, the time taken by the film to form has long been used to estimate the temperature of the metal. Equation (3) shows that δ also depends on the mean rate of cooling V which varies with such factors as weight of metal, shape of test-piece and its rate of loss of heat. In practice, this rate is obtained from the slag itself and varies with the physical state, chiefly the viscosity, of the slag. This explains a very puzzling phenomenon. When the slag is clear, the time for film formation is less than the real temperature would indicate, the reason being that the film is thin, so that V is large and δ small. The contrary is the case with a thick slag, owing to excess lime or falls of lining. These variations may mislead the melter and it is for this reason that a reading of the time taken by the film to form in the hand ladle serves as a useful check, especially as it is not such a delicate operation as using a pyrometer.

Equation (3) gives

$$T_0 = V\delta + \Theta \quad .. \quad .. \quad (5)$$

where Θ is the melting point of the metal. V can be determined experimentally by a few tests. This gives a much more precise means of checking the heat of the metal than by appearance alone and also gives a number which permits of comparisons, which is not possible with purely visual estimation.

Degree of Oxidization. The time of the film to form decreases very rapidly with oxidization so that it can be measured. Table II gives a cast of semi-hard steel (0·3 per cent C) deoxidized under a reducing slag. This sensitive method is very useful and is employed by Ranque[2] in his new method of steel making.

The reason can be deduced from the fact that oxidization reduces the surface tension of molten metal. An impurity which reduces the surface tension accumulates on the surface. Consequently, the oxygen in the mass of the steel comes to the surface and helps in forming the film, so that it is sufficiently thick to be stable before the melting temperature is reached. The content of *FeO* necessary to cause this is very small, not more than 0·005 per cent.

TABLE II. Variation of time for film formation with oxidization.

Test No.	Oxygen content per cent.	*FeO* content per cent.	Temperature deg. C.	Time seconds
1	0·028	0·125	1720	0 (steel boiling)
2	0·023	0·100	1720	5 (steel boiling)
3	0·020	0·090	1720	20 (steel calm)
4	0·016	0·070	1720	30 (steel calm)
5	0·007	0·031	1720	75

Chemical Composition. The shape of the blooms depends on the composition of the metal. It is very definite in cast iron[3]. For steel it is much less definite, but it can be used to identify certain classes of steel, e.g. ruchings for high manganese, parallel streaks for high chrome and large blobs with radial branches for high silicon steels. Certain tree-like effects appear to correspond to the quality of the steel.

Colour and Mobility. Colour depends firstly on temperature and also on composition. Carbon and silicon give a deep blue tint, manganese a violet tint, oxidization a yellowish tint. With hydrogen the tint is blue violet, the appearance oily or velvety and the blooms very few and immobile. These characteristics show up excessive gas content, which may lead to serious defects.

The mobility of the blooms is a surface phenomenon, similar to camphor in water, and due to variations in surface tension by local dissolution of *FeO*. It declines with temperature. High silicon content and hydrogen reduce mobility, owing to energetic reduction of oxides or increase in surface tension. The normal emissive power is 0·37, with excess hydrogen it falls to 0·33 and oxidization can raise it to 0·40.

Crystallization. It has been observed that crystallization was finer in proportion as the time of film formation was increased. The reason is not known but it must depend on variations in surface tension.

Quality Estimation. The tint, appearance, shape and mobility of the bloom give useful information on the quality of the metal and its gas and oxide contents. But the time of film formation is still the most useful method. If percentage of good casts is plotted against time of film formation a curve is obtained such as shown in Fig. 3. High values of δ correspond to excess hydrogen, lower values to heavy oxidization which lead to poorer metal. The curve confirms that these two phenomena are mutually exclusive.

III. PHYSICO-CHEMICAL FACTORS IN RELATION TO FILM FORMATION.

Diffusion. This is of particular interest in the speed of decarburization in the Siemens-Martin furnace. Some authors have related this speed to the speed of the reaction of carbon on *FeO* but theory does not agree with

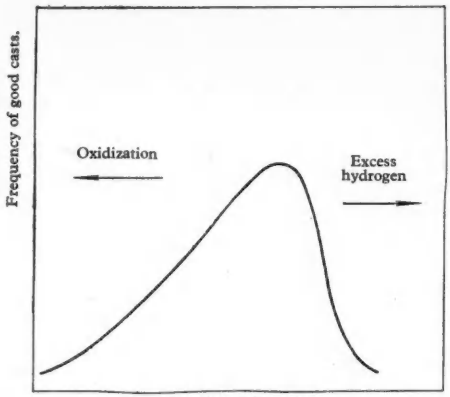


Fig. 3. Variation of the temperature of film formation as a function of the percentage of good casts.

practice. De Loisy[4] showed that two phenomena were present, a chemical reaction and diffusions. The slower diffusions regulate the speed. But his solution is incorrect because it is *FeO* which diffuses from the slag into the metal.

Fig. 4 shows carbon content as a function of time. The full line indicates experimental results, whereas the dotted line gives the theoretical curve. In the example chosen, the coefficient of diffusion D is about 10^{-2} units C. G. S., much greater than with ordinary liquids owing to the working of the metal by the release of *CO*. With decreasing speeds of decarburization, D decreases, and its time value for zero speed can be obtained by extrapolation. Working at various temperatures, the law of variation of the coefficient of diffusion can be obtained as

$$D = 27\, e^{-\frac{45000}{RT}} \quad .. \quad .. \quad (6)$$

which agrees closely with direct measurements.

Surface Tension. This has been measured by the large drop in air method as $A = 1200$ dynes/cm.

It increases with silicon and hydrogen contents (1400 for 2 per cent Si). But the study of surface phenomena is yet more instructive as the following two examples go to show.

(A). The calming of steel is a very mysterious phenomenon. Steel makers believe that it comes from superposition of oxidization (removal of oxygen by reducers, silicon or aluminium) and elimination and neutralization of gases, which would otherwise cause blowholes, etc. These two effects are simultaneous and whilst the first is well understood, the second is not. We can assume that deoxidization produces a fine precipitate of SiO_2 or alumina which holds the gases, probably by an irreversible surface phenomenon. It can be objected that the adsorption disappears under heat but the SiO_2 and alumina must be very adsorbent at the very high temperatures at which they are formed. Chaudron[5] has shown the great stability of gases contained in metals which seems to exclude the possibility of a simple solution.

The action of the precipitate is greater when it is finer and more abundant, as it is in the Siemens-Martin furnace, so that Siemens steel is easier to kill than electric steel, as experience shows.

(B). Slags ; it would be most interesting to know their chemical state when liquid in order to study their reactions. The molecular mass of a liquid can be calculated if its surface tension can be measured at two different temperatures and this gives an indication of its constitution.

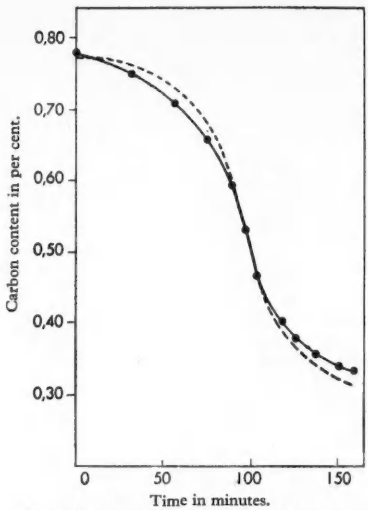


Fig. 4. Law of the variation of carbon content as a function of time.

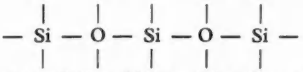
So a slag of the following composition

SiO_2	=	20·3	per cent
CaO	=	55	„ „
Al_2O_3	=	7	„ „
MgO	=	4·1	„ „
FeO	=	2·1	„ „
CaF_2	=	0·9	„ „ gave
A	=	500 dynes/cm. at 1550 deg. C.	
A	=	470 dynes/cm. at 1680 deg. C.	

whence the apparent molecular mass $M = 95$. It is deduced that the slag is formed of silicate $SiO_2\ 2CaO$, the other constituents being free, which gives a mean molecular mass of $M = 105$. The difference is explained by a partial combination of lime and *FeO*.

The surface tension of basic slags varies from 300 to 700 dynes, and slags do not foam when it exceeds 450 or 500 dynes.

Viscosity. The measurement of viscosity allows of study of the composition of liquid slags. It is known that SiO_2 gives long branch chains of molecules of the form



similar to that of oils which explains the extreme viscosity of glass. Silicates, on the other hand, can have very different viscosities, according to the elongated or branched form of their molecules.

It has been shown of what great interest is the study of blooming from the valuable information it gives to the practical man and from the explanation and interpretation it gives to certain reactions in steel making.

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OPERATION OF CENTRIFUGAL PUMP AND RECIPROCATING PUMP IN SERIES.

By L. S. LEIBENSON. (From *Bulletin of the Academy of Sciences of the USSR, Technical Class*, 1945, No. 6, pp. 491-496, 6 illustrations.)

ACCORDING to a proposal made by V. S. Kazmin the number of strokes per minute of a reciprocating pump can be increased by installing a centrifugal pump in its suction line. An arrangement of this kind is shown in Fig. 1 where the centrifugal pump is directly connected with the suction side of the reciprocating pump by means of a pipe of the length l. The delivery characteristic $Q = Q(\varphi)$ of the reciprocating pump is given in Fig. 2, where $\varphi = \omega . t$ is the crank angle, ω the angular velocity of the crank, and t the time.

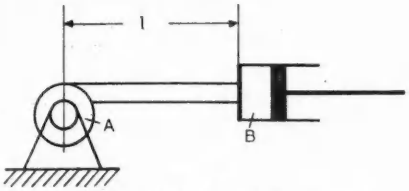


Fig. 1. *A*—Centrifugal or propeller type pump
B—Reciprocating pump

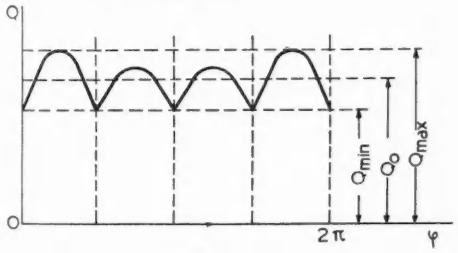


Fig. 2

The Q-H characteristic of the centrifugal pump for a given pump speed is shown in Fig. 3, where H is the delivery pressure of the centrifugal pump in terms of metres static head. Both in Fig. 2 and Fig. 3 Q_0 signifies the mean rate of delivery, while H_0 is the mean delivery head of the centrifugal pump. The delivery characteristic Q-H is established on the basis of steady flow conditions, but it will be assumed to be applicable also to unsteady flow. In computing the pressure pulsations arising in operation, the pressure obtaining at the delivery side of the centrifugal pump can therefore be found as the pressure coincidental with a given momentary rate of discharge Q according to the Q-H characteristic.

By applying this method to the delivery characteristic Fig. 2, the corresponding pressure characteristic Fig. 4 is obtained. The pressure H_B existing at the suction inlet of the reciprocating pump is given by

$$H_B = H_A - \zeta \frac{v^2}{2g} - \frac{l}{g}\frac{dv}{dt} \quad .. \quad (1)$$

where H_A is the pressure at the delivery side of the centrifugal pump, v the velocity of flow in the pipe of the length l which connects the delivery of the centrifugal pump to the suction of the reciprocating pump, ζ the coefficient of friction comprising all the hydraulic losses occurring in the connecting pipe and also the losses in the suction valve of the reciprocating pump ; and dv/dt is the acceleration of the liquid contained in the connecting pipe.

As the delivery characteristic $Q = Q(\varphi)$ is known, equation (1) can be solved and the characteristic $H_B = H_B(\varphi)$ can be established. The minimum permissible pressure H_B will then be given by the requirement that

$$(H_B)_{min} > (H_A)_{min} - \zeta \frac{v^2}{2g} - l . r . \frac{\omega^2}{g} \quad .. \quad (2)$$

where r is the crank radius. The pressure pulsations ΔH must therefore satisfy the condition

$$\Delta H_B < \Delta H_A + \zeta \frac{v^2_{max} - v^2_{min}}{2g} + 2l \cdot \frac{r . \omega^2}{g} \quad (3)$$

If the pressure $(H_b)_{min}$ should be found to be unduly low in a given case, then either the pressure $(H_a)_{min}$ must be raised by increasing the speed of the centrifugal pump, or an air vessel must be installed in the connecting pipe (Fig. 5). The pressure fluctuations obtaining in the latter system can be computed as follows :

It will denote :

Q_A the delivery of the centrifugal pump ;
Q_B the delivery of the reciprocating pump ;
V_0 the average volume of air contained in the air vessel ;
p_0 the average air pressure in the air vessel ;
y the decrease in air volume in the vessel at a given point of time t.

Assuming isothermal compression and expansion of the air in the air vessel, it is

$$p_0 . V_0 = (p_0 + p_c)(V_0 - y) \quad .. \quad (4)$$

where p_c is the pressure in excess of the average pressure p_0. If y is assumed to be small as compared with V_0, and if p_c is assumed to be small as compared with p_0, then

$$V_0 - y = \frac{p_0 V_0}{p_0 + p_c} \approx V_0 \left(1 - \frac{p_c}{p_0}\right)$$

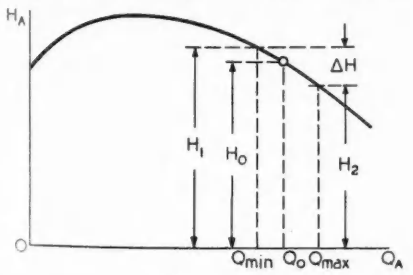


Fig. 3

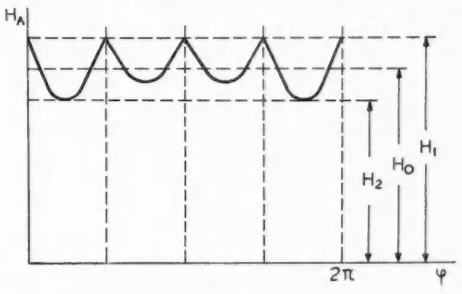


Fig. 4

Hence
$$\frac{dy}{dt} = \frac{V_0}{p_0} \cdot \frac{dp_c}{df} \quad .. \quad .. \quad (5)$$

But dy/dt is the difference between the discharges Q_A and Q_B, that is, the amount of liquid forced into the air vessel. Therefore

$$\frac{V_0}{p_0} \cdot \frac{dp_c}{dt} = Q_A - Q_B \quad .. \quad (6)$$

The fluctuations in the discharge Q_A and in the pressure p_A will be assumed to be small as compared with $(Q_A)_0$ and $(p_A)_0$ respectively. It will further be assumed that the operating range of the pump is confined to the descending branch of the Q-H characteristic (Fig. 6). In this case the operating condition at point $(Q_A)_0$, $(p_A)_0$ will coincide with the tangent MN in that point. The equation of this tangent will then be

$$p_A - (p_A)_0 = k\,[(Q_A)_0 - Q_A] \quad .. \quad .. \quad (7)$$

where values of $k>0$ will be coordinate with the descending branch of the characteristic, and values of $k<0$ with the ascending branch. From equation (7) it follows that

$$Q_A = (Q_A)_0 - \frac{p_A - (p_A)_0}{k} \quad .. \quad .. \quad (8)$$

Obviously it is

$$p_0 + p_c = p_A - \frac{\gamma \cdot l_1}{g \cdot f_1} \frac{dQ_A}{dt} \quad .. \quad (9)$$

where l_1 is the distance between the centre of the impeller of the centrifugal pump and the air vessel (Fig. 5), while f_1 is the cross sectional area of the connecting pipe, and γ is the specific gravity of the liquid. The hydraulic resistance of the length l_1 will be neglected. By combining equations (6) and (9) we have

$$\frac{V_0}{p_0}\left(\frac{dp_A}{dt} - \frac{\gamma \cdot l_1}{g \cdot f_1}\frac{d^2Q_A}{dt^2}\right) = Q_A - Q_B \quad (10)$$

and by further combining with equation (8), it becomes

$$\frac{V_0}{p_0}\left(\frac{dp_A}{dt} + \frac{\gamma \cdot l_1}{k \cdot g \cdot f_1}\frac{d^2p_A}{dt^2}\right) = (Q_A)_0 - \frac{p_A - (p_A)_0}{k} - Q_B$$

By making

$$p_A - (p_A)_0 = p \quad .. \quad .. \quad (11)$$

we obtain

$$\frac{V_0}{p_0}\left(\frac{dp}{dt} + \frac{\gamma \cdot l_1}{k \cdot g \cdot f_1} \cdot \frac{d^2p}{dt^2}\right) + \frac{p}{k} = (Q_A)_0 - Q_B \quad (12)$$

This equation reveals the important fact that stable operation of the arrangement under consideration is conditional upon operation on the descending branch of the characteristic, since only in this case p and its derivatives will be positive. Should the operating range be located on the ascending branch of the Q-H characteristic, then the coefficient k, as has been shown above, will be negative, and according to equation (12) the fluctuations of p will increase unhindered, that is to say, the system will be unstable. But in the stable operating condition only the impressed pulsations will be of importance.

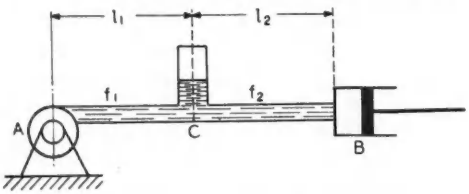


Fig. 5. *A*—Centrifugal or propeller type pump
B—Reciprocating pump
C—Air vessel

The discharge characteristic of the reciprocating pump can be expressed by a Fourier function of the form

$$Q_B = (Q_B)_0 + \sum_m Q_m e^{i.m.\omega.t} \quad .. \quad (13)$$

where the coefficients can be determined by analysing the actual characteristic as given in Fig. 2. Equation (12) can therefore be written

$$\frac{V_0}{p_0}\left(\frac{dp}{dt} + \frac{\gamma.l_1}{k.g.f_1}\frac{d^2p}{dt^2}\right) + \frac{p}{k} = -\sum_m Q_m e^{i.m.\omega.t}$$

or

$$\frac{d^2p}{dt^2} + \frac{k.g.f_1}{\gamma.l_1}\frac{dp}{dt} + \frac{g.f_1.p_0}{\gamma.l_1.V_0}p = -\frac{k.g.f_1.p_0}{\gamma.l_1.V_0}\sum_m Q_m e^{i.m.\omega.t} \quad (14)$$

The integral of this equation takes the form

$$p = \sum_m p_m . e^{i.(m.\omega.t - \delta_m)} \quad .. \quad (15)$$

which yields

$$p_m = \frac{-k \cdot Q_m}{\sqrt{\left[1 - \frac{l_1(m\omega)^2}{g} \cdot \frac{V_0 \cdot \gamma}{f_1 \cdot p_0}\right]^2 + \left(\frac{k \cdot m \cdot \omega \cdot V_0}{p_0}\right)^2}}$$

and

$$\tan \delta_m = \frac{k \cdot m \cdot \omega \cdot V_0}{p_0\left[1 - \frac{l_1(m \cdot \omega)^2 \cdot V_0 \cdot \gamma}{g \cdot f_1 \cdot p_0}\right]} \quad (16)$$

For practical purposes it will be sufficient to determine the first or the first two harmonics. Once p and $p_A = (p_A) + p$ are found, p_c and p_B can also be computed without much difficulty, the pressure p_c being obtained by combining equations (8) and (9) so that

$$p_0 + p_c = p_A + \frac{\gamma \cdot l_1}{k \cdot g \cdot f_1}\frac{dp_A}{dt} \quad .. \quad (17)$$

Furthermore, as Q_B is a known function of the time, p_B can be found from

$$p_B = p_A + \frac{\gamma \cdot l_1}{k \cdot g \cdot f_1}\frac{dp_A}{dt} - \frac{\gamma \cdot l_2}{g \cdot f_2}\frac{dQ_B}{dt} \quad .. \quad (18)$$

By combining equations (16), (15), (11), and (18), it

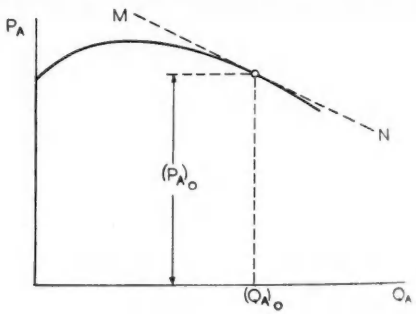


Fig. 6.

then becomes

$$p_B = (p_B)_0 - \sum_m \frac{k \cdot Q_m}{\sqrt{\ldots}} \left[e^{i(m.\omega.t - \delta_m)} + \frac{\gamma . l_1 . m . \omega}{k . g . f_1} \cdot e^{i(m.\omega.t - \delta_m + \pi/2)} + \frac{\gamma . l_2 . m . \omega}{k . g . f_2} e^{i(m.\omega.t + \pi/2)} \right] \quad (19)$$

Here $(p_B)_0$ is the actual mean pressure at the suction side of the reciprocating pump, taking account of the hydraulic losses which can be computed an the basis of the delivery rate Q_0. The symbol $\sqrt{\ldots}$ represents the square root given in formula (16). The minimum value of the first harmonic $(p_B)_{min}$ is determined by

$$(p_B)_{min} > (p_B)_0 - \frac{k \cdot Q_m}{\sqrt{\ldots}} \left[1 + \frac{\gamma . m . \omega}{k . g} \left(\frac{l_1}{f_1} + \frac{l_2}{f_2} \right) \right] \quad (20)$$

For reciprocating pumps of usual design, Q_m and m will depend upon the type of pump used, and it will be

(1) for simplex pumps : $m = 1$; $Q_m = \frac{1{\cdot}71}{\pi} F.r.\omega.$

(2) for duplex pumps : $m = 2$; $Q_m = \frac{4}{3\pi} F.r.\omega$

(21)

(3) for triplex pumps : $m = 6$; $Q_m = \frac{6}{35\pi} . F.r.\omega$

(4) for quadruplex pumps $m = 4$; $Q_m = \frac{8}{15\pi} . F.r.\omega$

where F is the piston area.

SWEDEN

BRITTLE FRACTURE OF STEEL UNDER SUSTAINED LOAD AT ELEVATED TEMPERATURE.

By C. SCHAUB. (From *Jernkontorets Annaler*, Vol. 130, No. 1, 1946, pp. 1-26, 8 illustrations.)

IN order to study the phenomenon of the brittle fracture of steel under sustained load at elevated temperature, a series of investigations was made at the Institute for the Investigation of the Strength of Materials of the Royal Swedish Technical University, Stockholm, during the years 1942-1944. The materials investigated are listed in Table I, which also gives the limiting creep stresses at 500 deg. C.

To obtain general information with regard to the tendency to embrittlement of the steels listed, specimens of the dimensions given in Fig. 1 were subjected to a 1,000 hr. test at 500 deg. C. The stresses to which the specimens were subjected are listed in Table II. Under these conditions the nominal stress in the notch corresponded to the short time creep limit of the material. Impact tests were carried out both before and after the 1,000 hr. test. From the results included in Table II, it is seen that Steel No. 4 and Steel No. 10, as well as Steel No. 15, exhibited a certain amount of embrittlement after the test, while Steel No. 7 is seen to have actually improved. This improvement can be explained by the special heat treatment of the material.

In view of these findings, further investigations were confined to the steels Nos. 6, 7, 10, and 15, the limiting creep strength of which lies in the range of 13-18 kg./sq. mm. When subjecting unstressed specimens of these steels to heating at 500 deg. C. for various lengths of time, the results listed in Table III were obtained. It will be seen that Steel No. 10 suffered increasing embrittlement with the test duration. This material is alloyed with approximately 0·65 per cent molybdenum and should not therefore exhibit temper embrittlement in the ordinary sense. It would, however, appear that this molybdenum percentage is not sufficient to prevent

TABLE I. Approximate analysis, heat treatment and strength of steels investigated.

Steel No.	C %	Si %	Mn %	Cr %	Ni %	Mo %	Ti %	Heat treatment†	σ_B kg/mm.²	Limiting creep stress kg/mm.²
1	0·12	—	—	13·5	—	—	—	—	—	—
2	0·10	—	—	17·0	—	—	—	—	—	—
3*	0·12	1·0	—	20·0	20·0	—	—	—	—	—
4	0·14	—	—	14·0	—	1·0	—	—	—	—
5	0·11	0·12	0·32	0·85	—	0·28	—	G700°/hr.	—	12
6	0·29	0·22	0·58	1·03	—	0·23	—	H850°/oil/700°	85	15
7	0·39	0·40	1·46	1·30	—	0·51	—	H850°/air/750°	87	15
8	0·10	0·15	0·40	—	—	0·45	—	N900°	40	13·5
9	0·15	0·15	0·80	1·0	—	0·35	—	N850°	59	19
10	0·25	0·25	0·50	0·7	3·25	0·65	—	H830°/oil/625°	102	18·5
11	0·08	0·50	0·45	18·0	9·0	—	0·5	G 1050°/water	61	16
12	0·15	1·50	1·00	25·0	20·0	—	0·5	G 1050°/water	61	18·5
13	0·08	—	—	18·0	9·0	—	—	G 1050°/water	65	20
14	0·15	—	—	5·0	—	0·5	—	heating	50	10·5
15	0·20	—	—	13·5	0·5	—	—	air hardening	> 70	13
16	0·15	0·20	1·00	1·2	—	0·4	—	heating	50	16

* Steel No. 3 exhibited deep longitudinal fissures and was therefore excluded from further investigations.

† G = heating, H = hardening, N = normalizing.

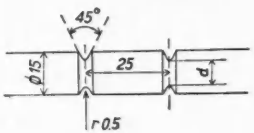


Fig. 1

TABLE II. Investigation of embrittlement in 1,000 hour test at 500 deg. C. at various loads (test-bars with circular notch).

Steel	σ_{nom} kg/mm²	Charpy test kg/cm	Charpy test specimen not heated kg/cm
1	15	> 1000	—
2	15	180	110
4	15	780	> 1000
5	12	> 1000	—
6	15	> 1000	—
7	15	740	410
8	14	> 1000	—
9	19	> 1000	—
10	18	200	> 1000
11	16	> 1000	—
12	18	> 1000	—
13	20	> 1000	—
14	10	> 1000	—
15	13	670	> 1000
16	14	> 1000	—

TABLE III. Influence of heating at 500 deg. C. upon Charpy impact strength at room temperature.

Heating time Hours.	Steel			
	6	7	10	15
0	15·2	2·5	9·8	8·7
24	15·0	4·8	6·3	8·1
72	15·2	7·0	5·7	7·7
210	15·7	7·1	3·3	8·9
332	14·2	7·2	3·0	8·9
648	16·0	6·9	3·0	8·2
984	14·6	7·0	3·4	8·6

Fig. 2a. **Microstructure of steel No. 10 showing fissures.** Magnification approx. 500 ×

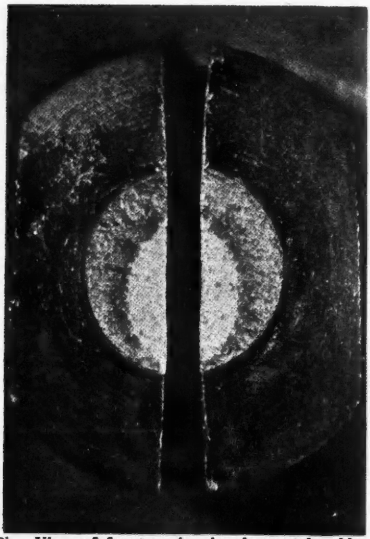


Fig. 2b. **View of fracture in circular notch.** Magnification approx. 4·5 ×

embrittlement in the case of extremely long heating time. This observation is in agreement with present day concepts regarding temper embrittlement. From Table III it will also be seen that—as was to be expected—the Steels Nos. 6 and 15 retain their original impact strength, while that of Steel No. 7 is actually greatly increased.

This test was followed by a time-for-rupture test at 500 deg. C., the test bars being provided with a circular notch (d = 7 mm.). In order not to extend the length of the test unduly, testing time was limited to periods not exceeding 2,000 hours. The results obtained are given in Table IV, from which the ratios time-for-rupture stress to limiting creep stress are derived as listed in Table V.

Referring to the latter table, it will be seen that Steel No. 10 exhibits the lowest and Steel No. 15 the highest strength at the test temperature. Metallographic inspection of the test-pieces of Steels No. 6, 7, and 15 failed to reveal the presence of any structural change or fissure formation at the circular notch. However, in the case of Steel No. 10, considerable (mainly inter-crystalline) fissures could be ascertained on the test pieces which had ruptured after 289, 438, 1,204, and 1,553 hours. A micrograph of a typical fissure and a macrograph of the fracture itself are given in Fig. 2a and Fig. 2b respectively. Referring to Fig. 2a, the fissures are seen to extend substantially at right angles to the direction of the tensile stress. These fissures appear to be intercrystalline and are in the form of branched-out communicating cavities, which are filled with an oxide (probably F_3O_4).

The time-for-rupture curves of the Steels Nos. 6 and 10 are also of interest, insofar as they intersect each other at the time T = 250 hours with the stress being σ_{nom} = 45 kg./sq. mm. For shorter times Steel No. 10 is the stronger one, while for times in excess of 250 hours, Steel No. 6 exhibits the greater strength. This is explained by the fact that the time-for-rupture characteristic of Steel No. 6 has a smaller slope than that of Steel No. 10. In view of the particular interest attaching to Steel No. 10 in this connection, another series of time-for-rupture tests was made with plain cylindrical test pieces. The results of these tests are listed in Table VI, which shows that the material fails to exhibit any tendency to embrittlement under tensile load for test durations up to 1,000 hours. Moreover, the fracture stresses consistently lie below those recorded with the notched specimens. The conclusion must therefore be drawn that the ordinary limiting creep stress test should be complemented by a corresponding test on notched test bars. In the latter test a stable material should not exhibit any tendency to embrittlement or to fissure formation in the notch similar to stress-corrosion.

TABLE IV. Stress-for-rupture test of test-bars (d = 7 mm.) with circular notch, at 500 deg. C.

σ_{nom} kg/mm²	Steel 6	Steel 7	Steel 10	Steel 15
	Hours			
60	28	—	59	—
55	38	464	98	—
50	75	596	123	850
45	369	1048	289	1412
40	900	1773	438	> 2000
35	1722	> 2000	1204	—
30	> 2000	—	1553	—
25	—	—	> 2000	—
20	—	—	—	—

TABLE V.

Steel	$\sigma_{2000\ hrs.}$	$\sigma_{2000\ hrs.}/\sigma_{creep}$
6	35 kg/mm²	2·3
7	39 ,,	2·6
10	30 ,,	1·6
15	42 ,,	3·2

TABLE VI. Stress-for-rupture test of smooth cylindrical test-bar of 7 mm. diameter (Steel No. 10).

σ, kg/mm²	Hours	
60	0·5	All failures are ductile and transcrystalline
55	1	
50	11	
45	28	
40	53	
35	140	
30	307	
25	> 1000	
20	—	

FRICTION FACTORS FOR PIPE FLOW.

By L. F. Moody,* (From *A.S.M.E. Transactions*, November, 1944, pp. 671-684, 7 illustrations.)

The object of this paper is to furnish the engineer with a simple means of estimating the friction factors to be used in computing the loss of head in clean new pipes and in closed conduits running full with steady flow. This paper is not intended as a critical survey of the wide field of fluid friction problems. For a concise review, Professor Bakhmeteff's small book on the mechanics of fluid flow is an excellent reference. Prandtl and Tietjens and Rouse have also made notable contributions to the subject. The author's aim is merely to embody the now accepted conclusions in convenient form for engineering use.

In the present pipe-flow study, the friction factor, denoted by f in the accompanying charts, is the coefficient in the Darcy formula

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

in which h_f is the loss of head in friction, in feet of fluid column of the fluid flowing; L and D the length and internal diameter of the pipe in feet; V the mean velocity of flow in feet per second; and g the acceleration of gravity in feet per second per second (mean value taken as 32·16). The factor f is a dimensionless quantity, and at ordinary velocities is a function of two, and only two, other dimensionless quantities, the relative roughness of the surface, $\frac{\epsilon}{D}$ (ϵ being a linear quantity in feet representative of the absolute roughness), and the Reynolds number $\mathbf{R} = \frac{VD}{\nu}$ (ν being the coefficient of kinematic viscosity of the fluid in square feet per second). Fig. 1 gives curves of f versus $\mathbf{R}$ plotted to logarithmic scales for various constant values of relative roughness $\frac{\epsilon}{D}$; and to permit easy selection of $\frac{\epsilon}{D}$, an accompanying chart (Fig. 2) is given from which $\frac{\epsilon}{D}$ can be read for any size of pipe of a given type of surface.

In order to find the friction loss in a pipe the procedure is as follows: Find the appropriate $\frac{\epsilon}{D}$ from Fig. 2, then follow the corresponding line, thus identified, in Fig. 1, to the value of the Reynolds number $\mathbf{R}$ corresponding to the velocity of flow. The factor f is thus found, for use in the Darcy formula.

In Fig. 2 the scales at the top and bottom give values of the diameter in both feet and inches. Fig. 1 involves only dimensionless quantities and is applicable in any system of units.

To facilitate the calculation of $\mathbf{R}$, auxiliary scales are shown at the top of Fig. 1, giving values of the product (VD'') for two fluids, i.e., water and atmospheric air, at 60 deg. F. (D'' is the inside diameter in inches). As a further auxiliary Fig. 3 is given, from which $\mathbf{R}$ can be quickly found for water at ordinary temperatures, for any size of pipe and mean velocity V. Dashed lines on this chart have been added giving values of the discharge or quantity of fluid flowing, $Q = AV$, expressed in both cubic feet per second and in U. S. gallons per minute.

To enable $\mathbf{R}$ to be quickly found for various fluids Fig. 4 includes an auxiliary diagram, which gives $\mathbf{R}$ for various values of the product VD'' shown by the diagonal lines. For any value of ν in the left-hand diagram, by following a horizontal line to the appropriate diagonal at the right, the corresponding $\mathbf{R}$ may be read at the top of the auxiliary graph.

Over a large part of Fig. 1 an approximate figure for $\mathbf{R}$ is sufficient, since f varies only slowly with changes in $\mathbf{R}$; and in the rough-pipe zone f is independent of $\mathbf{R}$. From the last consideration it becomes possible to show in the right-hand margin of Fig. 2 values of f for rough pipes and complete turbulence. If it is seen that the conditions of any problem clearly fall in the zone of complete turbulence above and to the right of the dashed line in Fig. 1, then Fig. 2 will give the value of f directly without further reference to the other charts.

ILLUSTRATION OF USE OF CHARTS.

Example 1: To estimate the loss of head in 200 ft. of 6-in. asphalted cast-iron pipe carrying water with a mean velocity of 6 ft./sec.: In Fig. 2 for 6 in. diam. (bottom scale), the diagonal for "asphalted cast iron" gives $\frac{\epsilon}{D} = 0{\cdot}0008$ (left-hand margin). In Fig. 3 for 6 in. diam. (left-hand margin), the diagonal for $V =$ 6 ft./sec. gives $\mathbf{R} = 2{\cdot}5\ (10^5)$ (bottom scale) (or, instead of using Fig. 3, compute $VD'' = 6 \times 6 = 36$). In Fig. 1, locate from the right-hand margin the curve for $\frac{\epsilon}{D} = 0{\cdot}0008$ and follow this curve to a point above $\mathbf{R} = 2{\cdot}5$ (10^5) on the bottom scale (or below $VD'' = 36$ on the top scale). This point gives $f = 0{\cdot}02$ (left-hand margin); then

$$h_f = f \frac{L}{D} \frac{V^2}{2g} = 0{\cdot}02 \frac{(200)}{(0{\cdot}5)} \frac{(6)^2}{64{\cdot}3} = 4{\cdot}5 \text{ ft. friction loss}$$

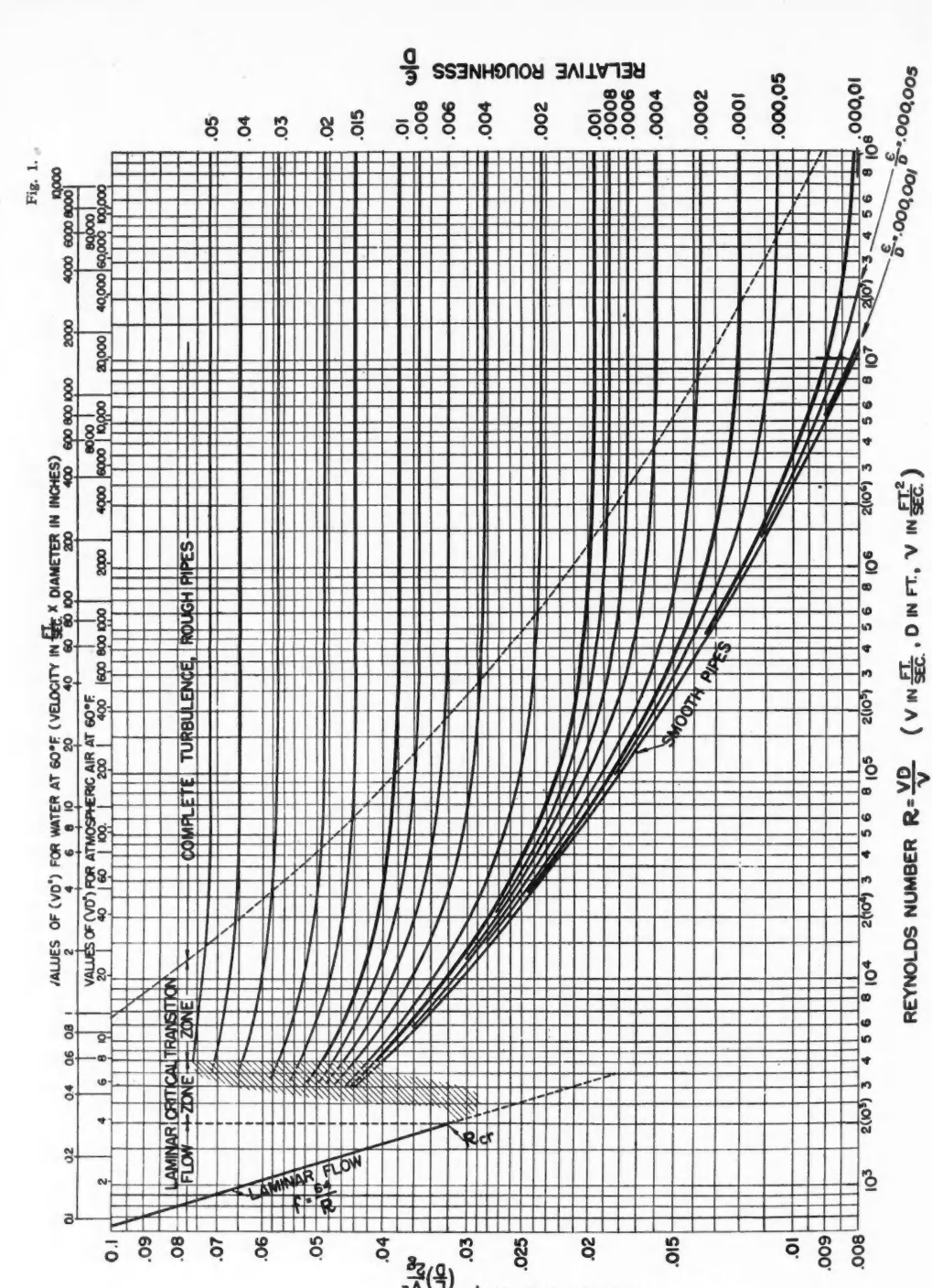
Example 2. To estimate the loss of head per 100 ft. in a 15-in. new cast-iron pipe, carrying water with a mean velocity of 20 ft./sec.: In Fig. 2, for 15 in. diam. (bottom scale), the diagonal for "cast iron" gives $\frac{\epsilon}{D} = 0{\cdot}0007$ (left-hand margin). In Fig. 3, for 15 in. diam. (left-hand margin), the diagonal for $V = 20$ ft./sec. gives $\mathbf{R} = 2\ (10^6)$ (or, instead of using Fig. 3, compute $VD'' = 20 \times 15 = 300$). In Fig. 1, the curve for $\frac{\epsilon}{D} = 0{\cdot}0007$ (interpolating between 0·0006 and 0·0008, right-hand margin), at a point above $\mathbf{R} = 2\ (10^6)$ (bottom scale) (or below $VD'' = 300$, top scale) gives $f = 0{\cdot}018$ (left-hand margin). In this case the point on Fig. 1 falls just on the boundary of the region of "complete turbulence, rough pipes." Here $\mathbf{R}$ or VD'' need only be approximated sufficiently to see that the point falls in the complete turbulence region, and f can then be found directly from the right-hand margin in Fig. 2 without further reference to Fig. 1; then

$$h_f = f \frac{L}{D} \frac{V^2}{2g} = 0{\cdot}018 \frac{(100)}{(1{\cdot}25)} \frac{(20)^2}{64{\cdot}3}$$

$= 8{\cdot}95$ or, say, 9 ft. friction loss.

* Professor, Hydraulic Engineering, Princeton University. Mem. A.S.M.E.

Fig. 1.


VALUES OF (VD') FOR WATER AT 60°F. (VELOCITY IN FT/SEC. X DIAMETER IN INCHES)
VALUES OF (VD') FOR ATMOSPHERIC AIR AT 60°F.
LAMINAR FLOW
CRITICAL TRANSITION ZONE
TURBULENCE, ROUGH PIPES
SMOOTH PIPES
FRICTION FACTOR $f = \frac{h_f}{(\frac{L}{D})\frac{V^2}{2g}}$
REYNOLDS NUMBER $R = \frac{VD}{\nu}$ (V IN $\frac{FT.}{SEC.}$, D IN FT., ν IN $\frac{FT^2}{SEC.}$)
RELATIVE ROUGHNESS $\frac{\varepsilon}{D}$
$\frac{\varepsilon}{D}$=.000,001
$\frac{\varepsilon}{D}$=.000,005

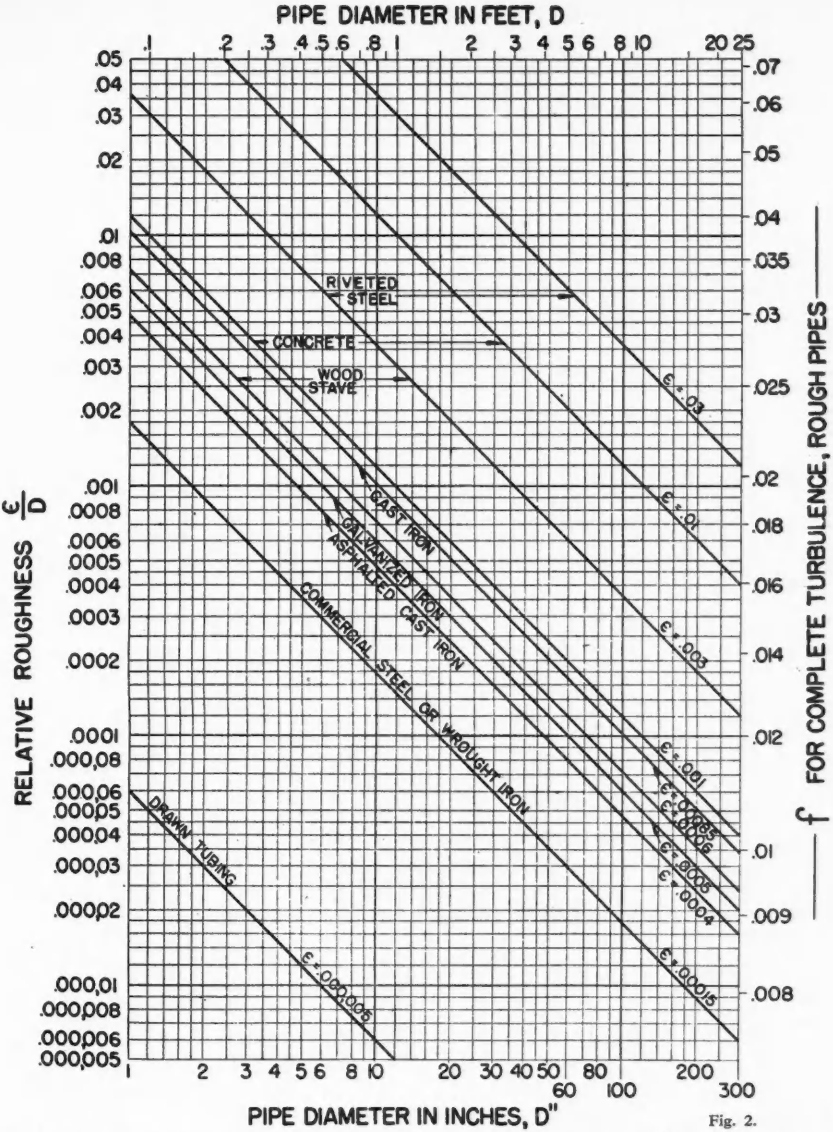


Fig. 2.

It must be recognized that any high degree of accuracy in determining f is not to be expected, as we lack the primary essential, a technique for measuring the roughness of a pipe mechanically.

Even with this handicap, however, fairly reasonable estimates of friction loss can be made, and, fortunately engineering problems rarely require more than this.

The charts apply only to new and clean piping, since the rapidity of deterioration with age, dependent upon the quality of the water or fluid and that of the pipe material, can only be guessed in most cases; and in addition to the variation in roughness there may be, in old piping, an appreciable reduction in effective diameter, making an estimate of performance speculative.

Where we have a sample of pipe of the surface texture in question available for test in the laboratory or in the field, from a test of such a pipe in any size we can, by aid of the charts, find the absolute roughness corresponding to its performance. Thus we have a means for measuring the roughness hydraulically.

The field covered by Fig. 1 divides itself into four areas representing distinct flow characteristics. The first is the region of laminar flow, up to the critical Reynolds number of 2000. Here the flow is fully stabilized under the control of viscous forces which damp out turbulence, permitting a completely rational solution. The values of f are here given by a single curve, $f = \frac{64}{R'}$, independent of roughness, representing the Hagen-Poiseuille law.

Between Reynolds numbers of 2000 and 3000 or

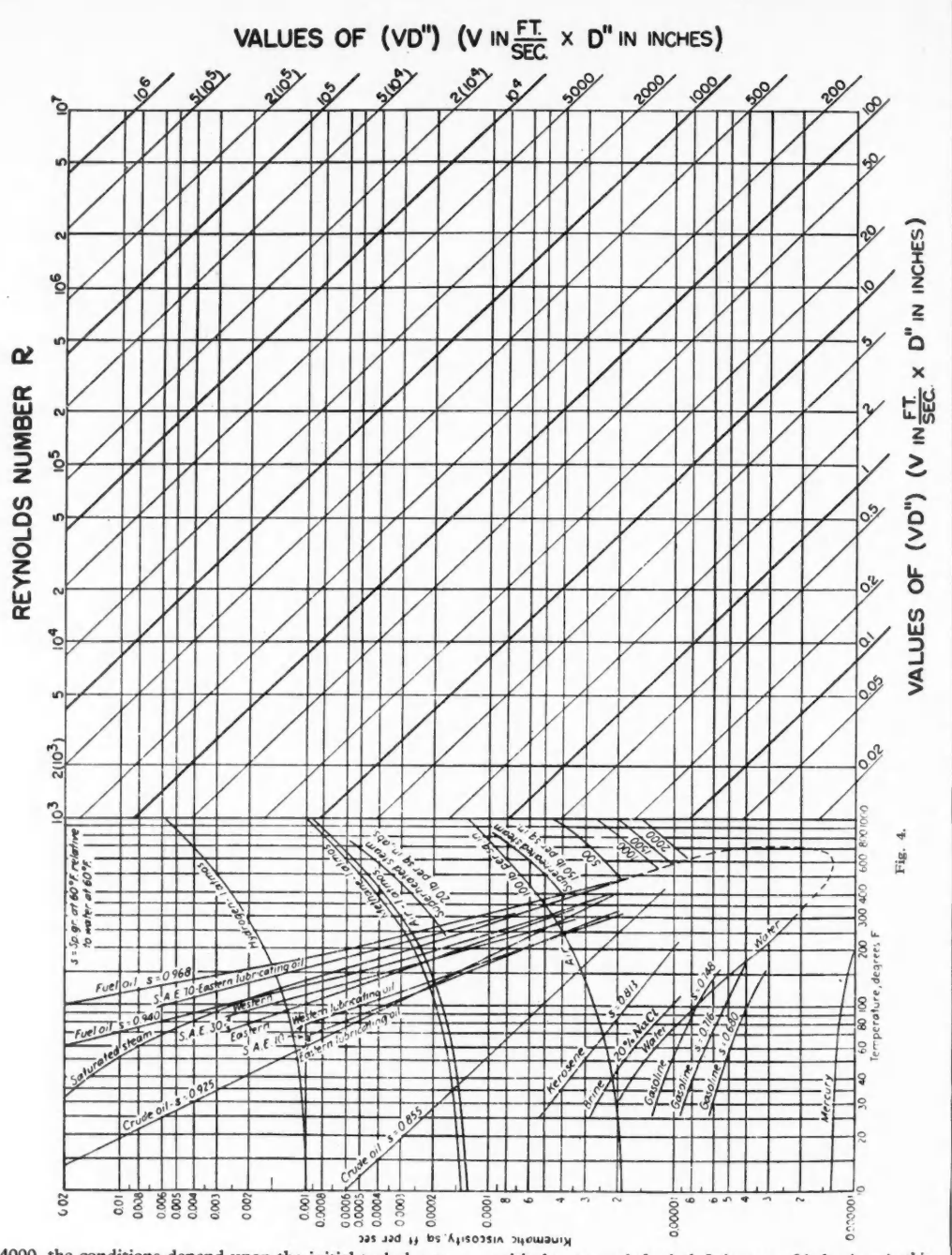


Fig. 4.

4000, the conditions depend upon the initial turbulence due to such extraneous factors as sudden changes in section, obstructions, or a sharp-edged entrance corner prior to the reach of pipe considered; and the conditions are probably also affected by pressure waves initiating instability. The region has been called a critical zone, and the indefiniteness of behaviour in this region has been indicated by a hatched area without definite *f* lines. The minimum limit for *f* values is the dotted continuation of the laminar-flow line, corresponding to very smooth and steady initial flow. When there is distinct turbulence in the entering fluid, the flow

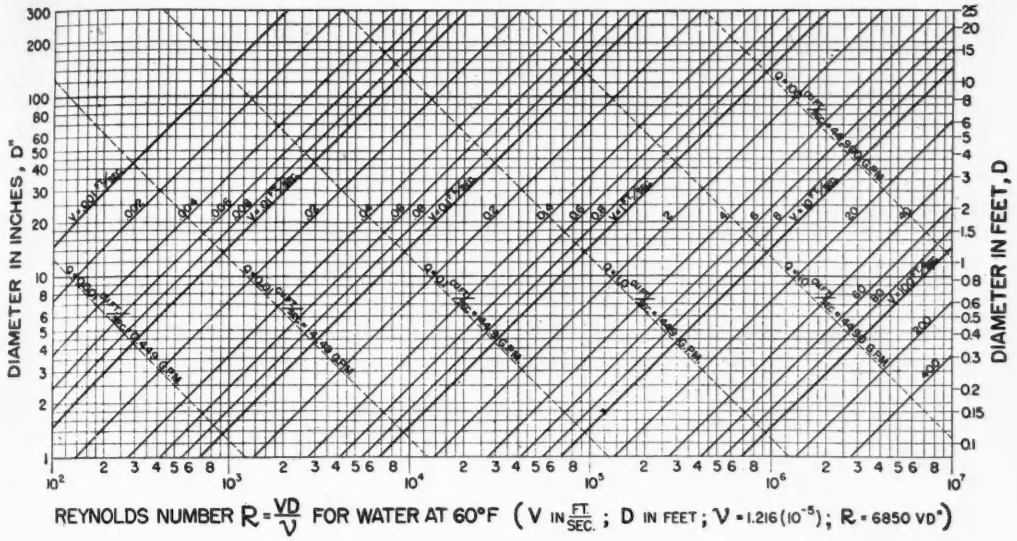


Fig. 3.

in the critical zone is likely to be pulsating rather than steady. The effects of strong initial turbulence may even extend into the laminar-flow zone, raising the f values somewhat, as far as to a Reynolds number of about 1200.

Above a Reynolds number of 3000 or 4000, conditions again become reasonably determinate. Here we find two regions, namely, the transition zone and the rough-pipe zone. The transition zone extends upward from the line for perfectly smooth pipes, for which the equation is

$$1/\sqrt{f} = 2 \log_{10} \frac{\mathbf{R}\sqrt{f}}{2{\cdot}51}; \text{ or } 1/\sqrt{f} = 2 \log \mathbf{R}\sqrt{f} - 0{\cdot}8$$

In the transition zone the curves follow the Colebrook function

$$1/\sqrt{f} = -2 \log \left(\frac{\epsilon/D}{3{\cdot}7} + \frac{2{\cdot}51}{\mathbf{R}\sqrt{f}} \right)$$

These curves are asymptotic at one end to the smooth pipe line and at the other to the horizontal lines of the rough-pipe zone. Actually, the curves converge rapidly to these limits, merging with the smooth pipe line at the left, and at the right, beyond the dashed line, becoming indistinguishable from the constant f lines for rough pipe.

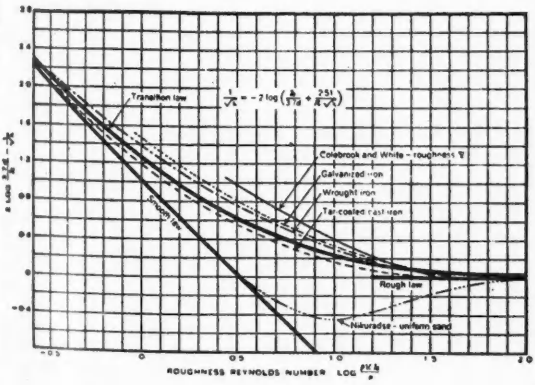


Fig. 5.

Colebrooke, using equivalent co-ordinates, plotted in Fig. 5 the results of many groups of tests on various types of commercial pipe surfaces. He found that each class of commercial pipe gave a curve of the same form, and these curves agree closely with each other and with a curve representing his transition function.

When the thickness of the laminar layer, which decreases with increasing Reynolds number, becomes so small, compared to the surface irregularities, that the laminar flow is broken up into turbulence, the flow conditions pass over into the zone of "rough pipes," with complete turbulence established practically throughout the flow. Viscous forces then become negligible compared to inertia forces, and f ceases to be a function of the Reynolds number and depends only upon the relative roughness, giving horizontal lines of constant f in the chart.

Since f depends upon the relative roughness, the ratio of the absolute roughness to the pipe diameter, even a fairly rough surface in a very large pipe gives a small relative roughness. Thus Colebrook plots the results obtained on the penstocks of the Ontario Power Company, where metal forms and specially laid concrete produced a very smooth example of concrete surface. This in combination with the large diameter gave a relative roughness comparable to drawn brass tubing, with f values falling practically on the "smooth pipe" line of Fig. 1. Such specially fabricated welded-steel pipe lines as those of the Colorado aqueduct system would probably give values along the same curve.

On the other hand, at very high velocities in drawn tubing of small diameter, even the small absolute roughness is sufficient to break up the laminar boundary layer, and the tubing becomes in effect a "rough pipe." Very few experiments have carried the velocities and Reynolds numbers high enough to permit a close estimate of ϵ for drawn brass, copper, or similar tubing; but ϵ was estimated as of the order of 0·000005; and a line corresponding to this value has been drawn in Fig. 2, serving as a minimum limit for surfaces likely to be encountered in practice.

HOLLAND

AN APPARATUS FOR STROBOSCOPIC OBSERVATION

By S. L. DE BRUIN (From *Philips Technical Review*, Vol. 8, No. 1, January, 1946, pp. 25–32, 14 illustrations).

NATURE still leads technology in sensitivity, but technical devices offer the advantage of much higher velocity and much greater precision. The eye is unable to follow phenomena which take place in less than 1/10 second. Cameras with focal plane shutters can work approximately 100 times as fast, and in this way record phenomena which are invisible to direct observation. The velocity of about 0·001 seconds thus obtained still fails, however, to meet the requirements made in many technical observations. With high-speed machines, for example, speeds up to 100 revolutions per second and translatory motion of up to 100m/sec are not exceptional. If in the latter case it is desired to fix accurately the momentary position of a part of a machine to within 1 mm, the observations may not last longer than 10^{-5} sec., and the moment of the observation must also be fixed accurately to within 10^{-5} sec.

A device commonly used to satisfy these requirements is the stroboscope. The action of the stroboscope is based upon the fact that it makes the objects to be investigated visible or photographable only at those moments at which the observation is desired.

One method of limiting the visibility of an object to certain periodically repeated moments consists in the use of a source of light which changes in intensity periodically. When a moving object is irradiated with such a light source, the strongest visual impression is received at certain moments, so that by correct choice of frequency and phase certain positions of the moving object can be emphasized.

In the case of non-periodic phenomena also the use of an intermittent light source offers improved possibilities of observation. A familiar experiment is the observation of an induction machine (Wimshurst machine) by the light of the jumping spark. The duration of the electrical flash-over is so short that the disks of the machine seem to stand still. Apparently the eye can receive a visual impression within any given short time interval provided the total amount of light is sufficient and the eye has time enough after the flash to assimilate the impression. It depends upon the nature of the phenomenon to be observed what devices must be used; mechanical, photo-electrical or acoustic devices can be employed.

In the following an apparatus will be described which is suitable for stroboscopic examination in laboratories and factories. This apparatus, type GM 5500, is so designed that a single flash as well as periodically repeated flashes can be obtained. The time interval between the flashes can be adjusted within wide limits, and the generator which excites the flashes can be synchronized with the part of the machine to be observed. The light intensity of the flashes is so great that the apparatus can be used at the brightness normally present in a room during daytime.

THE FLASH LAMP.

As already stated, the flash of an electric discharge is used. Now, for a permanent set-up, it is undesirable that the spark should occur in air, because the electrodes would be too strongly attacked. The obvious solution is to use a rare gas instead of air. The spark gap is thus constructed as a discharge lamp filled with a rare gas.

The best results were obtained with argon at a high pressure. The higher the pressure, the greater the intensity of the light of the flash-over. A limit is set to the pressure by the requirement that the flash-over voltage must not be too high and that a reasonable length of life must be ensured for the lamp.

The light of the high-pressure argon lamp is a bluish white and has a continuous spectrum with a high photographic actinity. It thus shows some resemblance to a water-cooled mercury lamp, which could also be used as flash lamp. However, due to the fact that there is no necessity for water cooling, the argon lamp is easier to handle and, moreover, possesses various advantages compared with the mercury lamp: it is always ready for use, while in order to obtain the necessary vapour pressure, the mercury lamp must first be warmed, and it has a shorter flash time, since the light emission of the mercury lamp is not only an electrical but in part also a thermal phenomenon, so that there is a certain phosphorescence due to the heat inertia of the mercury vapour.

After a detailed investigation of the most favourable combination of gas pressure, separation of electrodes and tube dimensions, a lamp with very good characteristics was designed. The flash time amounts to about 10^{-5} sec.; within this time an amount of light of 200 lumen seconds is emitted and an energy of 2W sec. consumed, so that the specific light flux amounts to 100 lm/W. This is about the same efficiency as can be obtained with a water-cooled mercury lamp of very high pressure.

The light flux during the flash is about 2×10^6 lm with a current of 2000 A and a power of 200 kW. In addition to these very high peak loads the lamp also receives a small continuous load in order to facilitate the breakdown. The total energy consumption is about 75W at, for example, 25 flashes per second.

The tube of the lamp consists of quartz and is mounted in a nitrogen-filled bulb. This is necessary, since with air filling the exterior of the hot quartz tube would be attacked by atomic oxygen which is formed due to the ionizing action of the ultraviolet radiation of the lamp.

The rear of the bulb is covered on the inside with a mirror and concentrates the light beam in a relatively small angle, so that an amplification of the illumination of about 75 times is obtained in the axis of the beam. At a distance of 2 m from the lamp the peak value of the illumination intensity in the axis is about 10^7 lux, which is sufficient for photography even with a strongly diaphragmed lens in the available time of 10^{-5} sec. The photographs given in this article were made with diaphragms F/16–F/22, so that it was possible to place the camera close to the object and still obtain great depth of focus.

Fig. 1 shows the stroboscope. The lamp is mounted on a rotating holder which is connected, by means of a

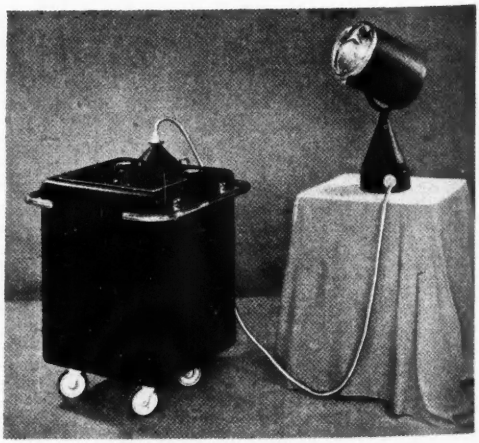


Fig. 1.—The Philips stroboscope GM 5500.

high-tension cable, to a cabinet on wheels containing the electrical apparatus. The light distribution of the stroboscope lamp is reproduced in Fig. 2.

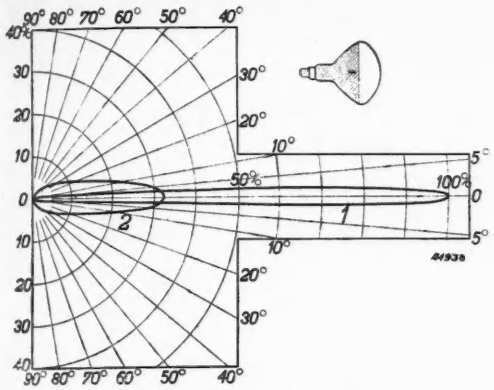


Fig. 2.—**Distribution of light intensity of a stroboscope lamp :** (1) with a clear (2) with a frosted bulb. The rear wall of the bulb is covered with a mirror in both cases. The scale of curve 2 is 10 times as large as that of curve 1, so that the maximum light intensity for the clear bulb is about 30 times greater than for the frosted bulb.

THE ELECTRICAL APPARATUS

The electrical apparatus must furnish electrical impulses of 2000 A with a duration of 10^{-5} sec. Depending upon the application it may be desirable to obtain single or periodically repeated discharges, while in every case it is important to be able to synchronize the moment of the breakdown with the phenomenon to be observed.

For feeding the flash lamp we use connexions with a relay valve which is ignited by a voltage impulse at the moments at which the discharges are required. The frequency at which these impulses, which are excited by a separate generator, are repeated can be regulated between 0·5 c/sec (30 impulses/min) and 250 c/sec (15,000 impulses/min). Moreover, it is possible to synchronize the impulses with a voltage led in from the outside. Finally the apparatus contains an electrical frequency meter which is coupled with the control generator.

The supply generator for the flash lamp.

The connections for the flash lamp are given in Fig. 3. *Via* a charging resistance R_1, a condenser C_1 is gradually charged to 600 V in order to be discharged again at certain moments *via* the relay valve and the flash lamp A, producing thereby the required current impulses.

The relay valve must be able to deal with several thousand amperes, while the average current amounts to less than 1 ampere. Taking into account these very abnormal conditions, a valve of special construction was designed and is shown diagrammatically in Fig. 4. On account of the low average load the dimensions of this valve were chosen relatively small, so that at each breakdown the electrodes are heavily overloaded. This overloading, however, has no harmful results since

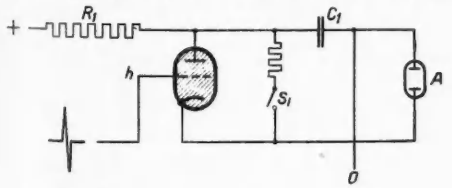


Fig. 3.—**Connexions for the supply of the flash lamp A by means of a condenser and a relay valve.**

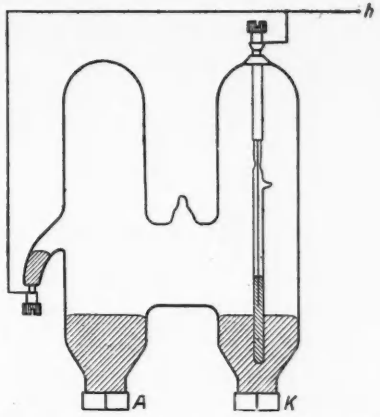


Fig. 4.—**Construction of the relay valve for the supply of the flash lamp.**

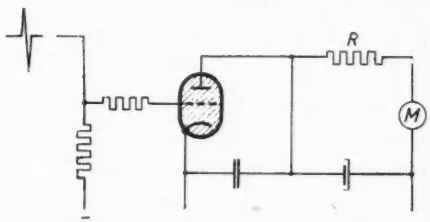


Fig. 5.—**Frequency meter connexions.**
The gas triode is blocked by a high negative voltage and only breaks down when a voltage impulse acts on the terminals which are connected to the control generator. The meter M measures the number of discharges per second of the condenser.

both electrodes consist of mercury. Only an intense evaporation of the mercury occurs during the current impulse. The vapour condenses in the glass domes over the electrodes and the condensed mercury drips back to the electrodes.

For the ignition of the relay valve an auxiliary electrode h is introduced at the cathode side, which upon application of a voltage impulse (about 8 kV), causes the occurrence of a cathode spot and thus initiates the discharge. The condenser is then discharged *via* the relay valve and the flash lamp, whereupon the relay is extinguished. If, due to the current supply *via* the charging resistance R_1, the relay valve should continue to burn, it may be extinguished by practically short-circuiting it during a short time by means of switch S_1.

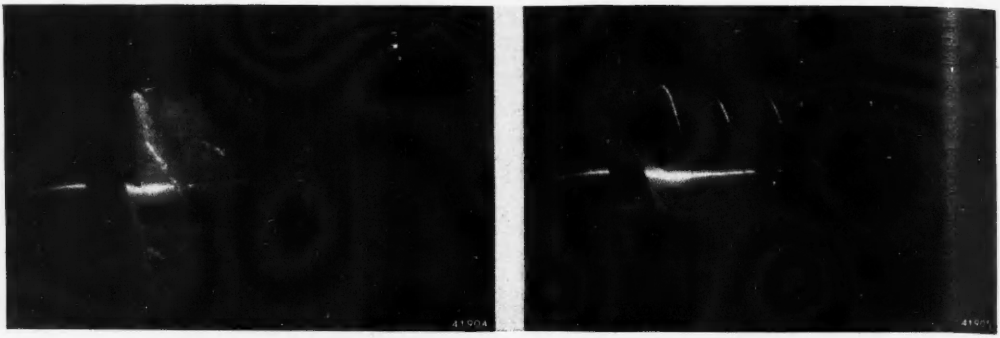
According to the application of the stroboscope there are different ways of synchronizing the voltage impulses which serve to ignite the relay valve, namely :

(a) with the AC voltage of the supply mains,
(b) with an AC voltage or voltage impulse of about 50 V from outside,
(c) mechanically, by breaking a contact,
(d) mechanically, by making a contact ; this is also used for electrical synchronization with a single voltage impulse.

In order to obtain synchronization voltages in the case of non-periodic phenomena, use may be made of a microphone or a photocell. Since these apparatus only give minimum voltages or currents, it is of course necessary to employ a suitable amplifier.

The frequency meter.

In order to be able to control accurately the number of flashes per second furnished by the stroboscope, the apparatus is provided with a frequency meter, which



(a) strong cavitation. **Fig. 6.—Ships' screws in cavitation tank.** (b) no cavitation.

indirectly measures the frequency by indicating the average charging current of a condenser which is discharged at each flash through the gas triode, to be charged again to a certain voltage. (See Fig. 5).

The gas triode of the frequency meter is controlled by voltage impulses which are taken from the same impulse voltage of 8 kV with which the relay valve of the supply generator is controlled. In addition to this impulse voltage there is also, on the grid of the gas triode, a negative bias of such magnitude that in the absence of an impulse no breakdown can occur. Since, at every breakdown, the condenser is almost completely discharged, the average current through the gas triode is equal to the charge of the condenser multiplied by the frequency of the voltage impulses. This current is indicated by a rotating coil instrument which is calibrated directly in number of flashes per minute.

APPLICATIONS.

In visual observation the stroboscope is especially suitable for rapid observations. By means of the frequency meter, frequencies of vibrations or other periodic movements can be determined. Interesting phenomena which occur in a certain phase of a motion can be recorded photographically.

Cavitation of ships' screws.

In order to study this phenomenon, models of screws are examined in a flow channel in which, by regulation of the velocity of the water, the water pressure, and the number of revolutions, cavitation can be faithfully reproduced. This " cavitation tank " is provided with glass observation windows through which stroboscopic illumination is possible. Photographs taken are shown in Fig. 6.

The cutting by the teeth of a planing machine.

In testing a planing machine it is important to know whether all the teeth take an equal share in the cutting process. This can easily be ascertained by stroboscopic observation of the machine in action.

Investigation of internal combustion engines.

The stroboscope may be usefully applied to the checking of such parts as the springs of a high-speed Diesel. This is important because the phase of the opening and closing of the valve may deviate from the phase adjusted with stationary motor.

Observation of liquids.

In certain applications of the stroboscope no synchronization of the light flash is necessary and particular advantage is drawn from the short exposure time. A practical application is found in the investigation of jets of liquid in the lubrication of machines for metal working. As an example Fig. 7 shows a photograph of the lubrication of a centreless grinding machine. It may be seen that the liquid is blown aside by the wind from the grindstone and thus does not flow over the grindstone as was intended.

OTHER APPLICATIONS

In addition to these examples there are, of course, numerous other possibilities for the stroboscope. An extensive field is formed by high-speed machines of the textile industry, such as spinning machines, looms and sewing machines. Less obvious is the application to material testing, where advantage can be taken of the possibility of photographing at exactly the right moment the very rapid process of the breaking of a work-piece.

Fig. 7.—Cooling of centreless grinding machine.

NEW DESIGNS OF TRANSFORMERS AND CHOKE COILS.

By A. MEYERHANS. (From *The Brown Boveri Review*, Vol. 32, No. 3, March 1945, pp. 91-100, 21 illustrations).

INTRODUCTION

WITH the ever-increasing voltages and capacities the limits of construction imposed by problems of transportation of transformers are gradually approached. This article describes two methods of solving future problems ; one consists of the use of cable-like insulation with the splayed flange, the other of the use of radially laminated transformer limbs with lateral yokes which, inter alia, reduces the overall height of the transformer.

THE SPLAYED FLANGE INSULATION.

In conventionally designed large capacity high voltage transformers, bakelized paper cylinders are usually fitted at regular intervals in a relatively large clearance between the windings. At the ends of the windings angle rings are inserted between the cylinders, the flange of which serves as a transverse insulation between the windings and the yokes (Fig. 1). The electrical stressing being in inverse proportion to the dielectric constants ϵ, the oil clearances ($\epsilon = 2{\cdot}2$) carry twice as many kV per cm. as the bakelized paper barriers ($\epsilon = 4\text{-}4{\cdot}5$). The higher breakdown strength of the bakelized paper is thus utilized only when the oil clearances break down and the paper barriers have therefore generally been so dimensioned that they could stand up to the full test voltage for a short time alone. In calculating the distance between the windings which would enable the oil to stand up to its stressing, however, the configuration of the field had to be taken into account. As a result, there was far more oil between the windings than was actually necessary for cooling purposes.

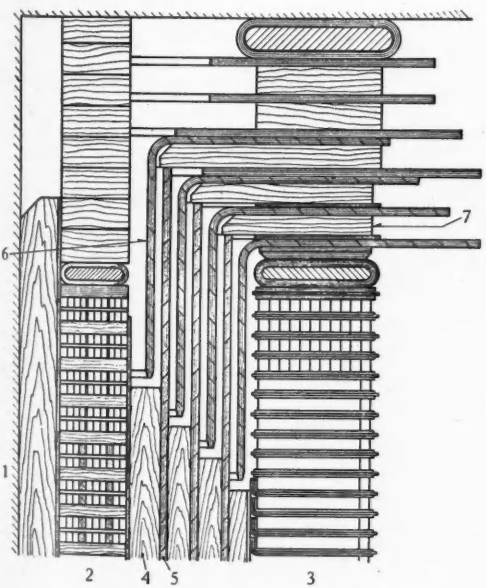


Fig. 1. **Section through old type transformer.**
Principal insulation : Oil with bakelized paper cylinders and angle rings.

1. Core
2. Low-voltage winding
3. High-voltage winding
4. Wooden strips
5. Bakelized paper cylinders
6. Bakelized paper angle rings
7. Spacers

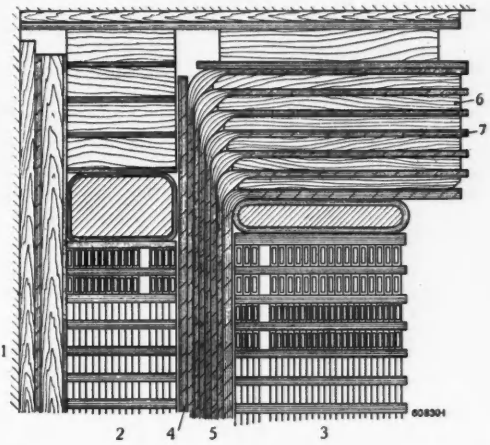


Fig. 2. **Section through winding of new type transformer.**
Principal insulation : oil impregnated paper cylinder with splayed flange.

1. Core
2. Low-voltage winding
3. High-voltage winding
4. Bakelized paper cylinder
5. Insulating paper
6. Shims
7. Paper flange

The use of oil-impregnated paper as main insulation for transformers was not practicable, as heavy tangential stresses were anticipated at the ends of the windings with consequent surface flash-overs around the ends of the paper cylinders. This problem has, however, now been solved by the introduction of the splayed flange cylinder.

Insulating paper as wide as the insulating cylinder is long is wound on to a relatively thin bakelized paper cylinder as former. The diameter and thickness of the latter are chosen so that the space between the low and high voltage windings is entirely filled up with the exception of a small clearance. Once the high-voltage winding has been fitted, narrow strips of the paper continually formed by scoring the end of the cylinder are bent over radially outwards around the protecting ring on the front of the winding. The scores are displaced from layer to layer so that the paper strips overlap well. From time to time the layers of paper are distanced by means of spacers. This splaying gives the end of the cylinder the necessary strength against surface flash-overs (Fig. 2). In addition, the strong tangential field component present in the conventional arrangement is considerably reduced.

The introduction of the splayed flange cylinder has enabled the distance between the high and low voltage windings to be reduced to less than half. However, the reduction in the weight of the oil required, the lower costs for the fixed insulating material, and the smaller dimensions of the oil tank, *directly* resulting from this feature, are of far less importance than the *indirect* effects of the reduction of the width of the leakage field channel.

The percentage leakage voltage, which, in the case of large transformers is practically the same as the impedance voltage, is for operational reasons generally a prescribed narrowly limited value. It is the ratio between the leakage and the main fluxes and as such it would, in conventional transformers, have become much

greater than was desirable, had the designer not increased the cross-section of the core. This, especially in large units, resulted in a disproportion between the weight of the core and the winding. The splayed flange, however, enables the optimum ratio to be attained even for high voltages.

As an example, the following comparison of two forced cooled three-phase oil-immersed transformers supplied to exactly the same specification is given. The new transformer, with splayed flange insulation has twice the rating of the other.

Year of construction		1931	1940
Insulation		old	new
Rating	kVA	10,000	20,000
Ratio		144,000 V	
		$6{,}835 \pm 10 \times 85{\cdot}5$ V	
No-load losses	kW	40 (31) *	33
Copper losses	kW	86	152
Weight without oil	tons	41	44
Weight of oil	tons	25·3	24
Overall weight	tons	66·3	68

*converted for the quality of the iron of the new transformer.

A 47,500 kVA transformer with a high voltage of 150 kV built for a power station weighs only 75 per cent. of a 26,000 kVA transformer built for the same station in 1928, though its rated capacity is 83 per cent. greater. A further notable feature of this particular transformer is the direct connection of the 150 kV oil-filled cable to the transformer with built-in disconnecting links.

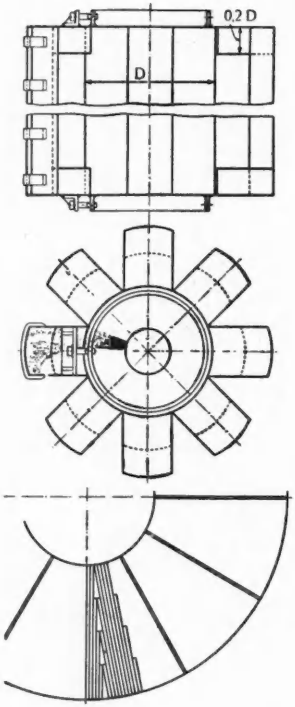


Fig. 3. Radially laminated core with angular return magnetic circuit.

Compared to the four-limb or shell core the yoke height is reduced still further by $2 \times 0{\cdot}3\,D = 0{\cdot}6D$

RADIALLY LAMINATED TRANSFORMER LIMBS

The chief difficulties as far as the transport problem of transformers is concerned are caused by the height. In the case of conventional three-limb core, the height of the yokes is approximately the same as the diameter *D* of the limbs, and in the case of the five-limb core, about one half of it. Radially laminated cores with annular magnetic return circuits (Fig. 3), however, can be kept as small as $0{\cdot}2D$.

The idea of using radial laminations of stepped-down width was known forty-five years ago, but only the development of electric welding has now enabled this to be realized. Since the magnetic flux no longer passes through the front of the limb, a closed iron ring can be welded on the active laminations there, thus giving a stable limb construction. If the return circuits are combined into U-shaped packets, connecting links can also be welded on to their upper and lower end surfaces, which enables the return circuit yokes to be pressed on to the limbs by non-magnetic bolts. This gives the advantage of the butt-joint core.

Although the individual packets of the limb are of different cross-section, the surface of the limb laminations serving to transfer the flux to the yoke laminations is the same for all packets, and the eddy currents produced by compensating flux from the large to the narrow packets are only very slight. On the other hand, bolt circuits are eliminated. The most important point, however, is that since the flux transfer from the limbs to the yokes takes place over a surface with the largest circumference as base, a yoke height of only about 0·2 times the limb diameter is necessary. The mean path of the flux is shorter and the weight of iron thus favourable. Moreover, the U-shaped return circuit yokes also serve as a winding support and the cylindrical form of the whole yoke and core system results in a very advantageous type of oil tank, a cylindrical case ; the transformer thus requires very little oil.

Three single-phase transformers of this type are only slightly more expensive than the corresponding three-phase transformer for large outputs. This type proves particularly advantageous when the high voltage system is operated with solidly earthed neutral point so that the single-phase transformer only requires one large bushing. Although not always superior to the conventional design—especially when only small outputs are required—the new design is particularly interesting for outdoor erection even down to 30 MVA three-phase output, apart from special applications.

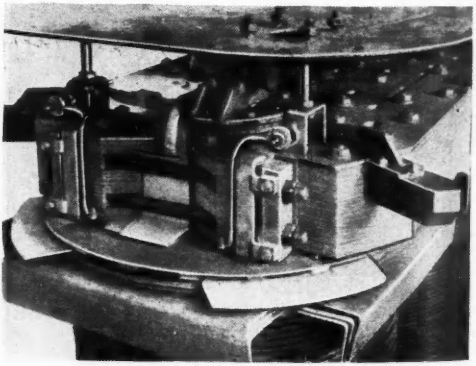


Fig. 4. Clamping yoke of two-limb core with radially-laminated limbs and transversely laminated yokes.

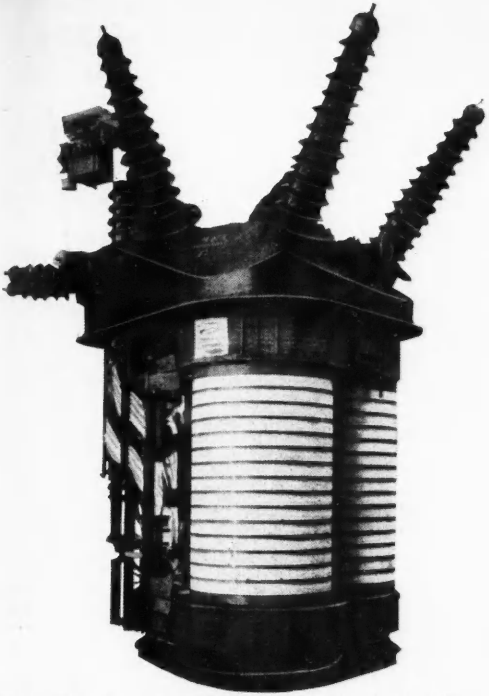


Fig. 5. **Transformer rated 23 MVA, for high voltage of 150 kV with three radially laminated limbs in triangular formation and transversely laminated yokes.**

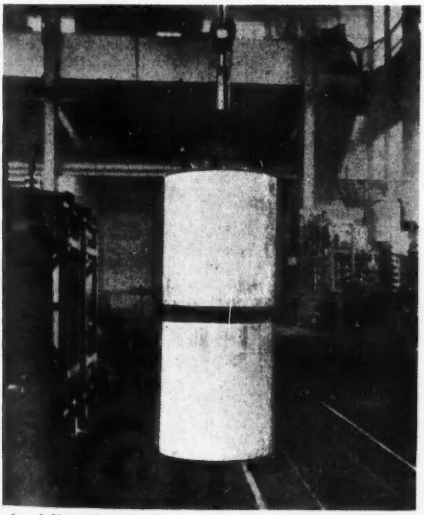


Fig. 6. **Adjustable limb stub with radial laminations on rotatable threaded spindle for a choke coil with stepless regulation.**

In special cases the design with two radially laminated limbs and transversely laminated yokes may be of advantage (Fig. 4). The height of the yokes is just as low as with the design with annular return magnetic circuit.

A three-phase design with three limbs in triangular formation is also possible (Fig. 5). A 30 MVA unit has already proved its reliability over a long period. The yoke plates each consist of three sectors of 120 degrees insulated from each other at their joints. The oil filling of the transformer illustrated, which has a rating of 23 MVA with a high voltage of 150 kV, weighs only 8·5 t, manifestly a milestone on the way to the low-oil-capacity transformer.

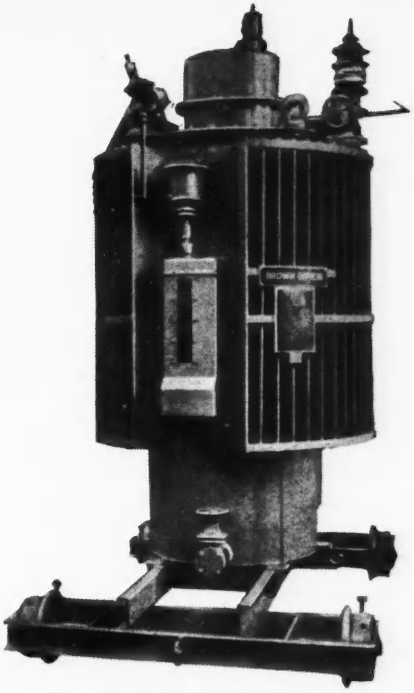


Fig. 7. **Arc suppression coil with stepless current regulation and built-on mechanical position indicator.**

With the triangular arrangement, however, marked additional losses unfortunately occur due to the local rotation of the magnetic field in the centre part of the yokes.

The radially laminated core has quite special fields of application in the regulating transformer with displaceable winding and the regulating choke coil with variable air gap.

In the case of the conventional parallel-laminated core of large choke coils, the width of the gap could not be regulated, but only the flux density, by varying the number of turns with the help of tappings. Due to the radially laminated core, large choke coils with variable air gap, i.e. without tappings on the winding, have become possible. This arrangement ensures smaller eddy-current losses. The gap can be made any desired width ; a spindle with non-magnetic centre piece and right and left hand threads on the ends permits the stub of the limb to be displaced (Fig. 6). The body of the annular return magnetic circuit is connected to a rigid frame which carries the spindle bearings in such a manner that the limb stub can move axially with only a slight clearance in the transverse yokes.

A large number of such choke coils in the form of Petersen coils with ratings up to 5,000 kVA and over have been in service for a long time ; air gaps of nearly 1 m. have been obtained without any trouble. The mechanical position indicator mounted on the progressively variable arc suppression coils permits the adjusted coil current to be read off (Fig. 7). A mechanism for automatic adjustment of the coil to momentary network conditions has already been developed.

CZECHOSLOVAKIA

ELECTRIC CIRCUITS WITH ALTERNATING RESISTANCES.

By J. Hak. (From *Elektrotechnicky Obzor*, Vol. 34, No. 11-12, September, 1945, pp. 161-164, 5 illustrations.)

Transient conditions during and following the making or breaking of connections in circuits with constant resistances, inductances and capacities are phenomena which have already been thoroughly investigated in the past, both experimentally and theoretically. On the other hand, transient and often even steady conditions in circuits in which resistances, inductances and capacities change as definite functions of time have been studied only in a few exceptional cases. This article deals with a circuit consisting of a constant inductance, an alternating resistance and no capacity. Such a circuit is of general interest and at the same time a very general solution can be reached purely mathematically which covers both the transient as well as the steady conditions and which is suitable for direct numerical application.

The differential equation

$$L\frac{di}{dt} + [R_0 + r\Phi_1(t)].\, i = E f_1(t),$$

of the circuit with the alternating resistance r_t (Fig. 1) is solved by substituting $i = \frac{E}{R_0}.\, y$ and $t = \frac{L}{R_0}\,\tau$, the general solution being

$$y = e^{-\int \Phi(\tau)\, d\tau} \cdot \left[\int e^{\int \Phi(\tau)\, d\tau} \cdot f(\tau)\, d\tau + C\right];$$

this is valid for any function $\Phi_1(t)$ according to which the resistance may change and for any voltage $Ef(t)$ applied to the circuit.

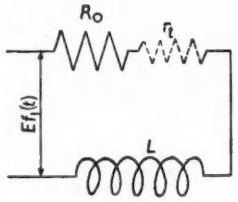


Fig. 1

If the resistance of the circuit consists of a constant (R_0) and an alternating (r_1) component, the resulting current is expressed by :

$$y = e^{-\tau} \cdot e^{\frac{A}{b}\cos(b\tau+\psi)} \left[\int e^{\tau - \frac{A}{b}\cos(b\tau+\psi)} \cdot f(\tau)\, d\tau + C\right]$$

which applies to any voltage $Ef_1(t)$.

From this equation further expressions are developed according to the function governing the voltage. Thus, for a D.C. voltage the transient conditions following the making of the circuit are described by

$$y = e^{\frac{A}{b}\cos(b\tau+\psi)} \left\{ (1 + e^{-\tau})\, T_0 + \right.$$

$$- \frac{T_1}{\sqrt{1+b^2}} [\cos(b\tau+\psi-\gamma_1) - e^{-\tau}\cos(\psi-\gamma_1)] +$$

$$\left. + \frac{T_2}{\sqrt{1+4b^2}} [\cos(2\tau+2\psi-\gamma_2) - e^{-\tau}\cos(2\psi-\gamma_2)] \mp \ldots \right\}$$

and the steady conditions by

$$y = e^{\frac{A}{b}\cos b\tau} \left[T_0 - \frac{T_1}{\sqrt{1+b^2}} \cos(b\tau-\gamma_1) + \right.$$

$$\left. + \frac{T_2}{\sqrt{1+4b^2}} \cos(2b\tau-\gamma_2) \mp \ldots \right]$$

For an A.C. voltage $e = E \sin \varphi t$ the transient conditions following the making of the circuit are expressed by

$$y = e^{\frac{A}{b}\cos(b\tau+\psi)} \left\{ \frac{T_0}{1+a^2}(\sin a\tau - a\cos a\tau + a e^{-\tau}) + \right.$$

$$- \frac{T_1}{2}\left(\frac{\sin[(a+b)\tau+\psi-\delta_1] - e^{-\tau}\sin(\psi-\delta_1)}{\sqrt{1+(a+b)^2}} + \right.$$

$$\left. + \frac{\sin[(a-b)\tau-\psi-\delta_{-1}] + e^{-\tau}\sin(\psi+\delta_{-1})}{\sqrt{1+(a-b)^2}} \right) +$$

$$+ \frac{T_2}{2}\left(\frac{\sin[(a+2b)\tau+2\psi-\delta_2] - e^{-\tau}\sin(2\psi-\delta_2)}{\sqrt{1+(a+2b)^2}} + \right.$$

$$\left. + \frac{\sin[(a-2b)\tau-2\psi-\delta_{-2}] + e^{-\tau}\sin(2\psi+\delta_{-2})}{\sqrt{1+(a-2b)^2}} \right) +$$

$$\left. + \ldots \right\}$$

and the steady conditions by

$$y = e^{\frac{A}{b}\cos(b\tau+\psi)} \left\{ T_0 \frac{\sin(a\tau-\delta_0)}{\sqrt{1+a^2}} + \right.$$

$$- \frac{T_1}{2}\left(\frac{\sin[(a+b)\tau+\psi-\delta_1]}{\sqrt{1+(a+b)^2}} + \frac{\sin[(a-b)\tau-\psi-\delta_{-1}]}{\sqrt{1+(a-b)^2}} \right)$$

$$+ \frac{T_2}{2}\left(\frac{\sin[(a+2b)\tau+2\psi-\delta_2]}{\sqrt{1+(a+2b)^2}} + \right.$$

$$\left. + \frac{\sin[(a-2b)\tau-2\psi-\delta_{-2}]}{\sqrt{1+(a-2b)^2}} \right) \mp \ldots \left. \right\}$$

Finally, the conditions following the breaking of the circuit (basic differential equation

$$L\frac{di}{dt} + [R_0 + r\sin(\omega t+\psi)]\, i = 0)$$

are expressed by

$$y = y_0\, e^{-\tau}\, e^{\frac{A}{b}[\cos(b\tau+\psi)-\cos\psi]}$$

The practical application of this theory is shown on three numerical examples.

QUENCHING ACTION IN RELATION TO CROSS SECTION.

By W. EILENDER, H. AREND and R. MINTROP. (From *Fertigungstechnik*, No. 8, August, 1944, pp. 208-212, 15 illustrations.)

THE increasing use of hardenable steels, slightly alloyed with scarce metals, has attracted attention to the processes involved in the improvements made by heat treatment. The influence of manufacture, the austenitic grain size, and the hardenability of steel have been the subject of numerous publications and are understood to a large extent. Improvements have been obtained by reducing the speed of transformation of the steel in the pearlite and intermediate stages, and it is possible to get further improvement by using more severe quenching media, e.g., water instead of oil. The disadvantage is the larger temperature difference set up between the surface and the core of the article during quenching. Thus, shrinkage and transformation stresses are increased. To keep this disadvantage within reasonable limits, the careful matching of severe quenching media with the type of steel and the dimensions of the work-picce are required. The decisive factor in this connexion is the "upper critical cooling speed," i.e., the minimum speed which will keep the austenitic state down to the martensite temperature.

The numerical determination of quenching media, by direct measurement of the cooling speed in articles of different shape and cross section, demands elaborate and difficult experiments, and is therefore hardly suitable for routine tests of quenching media. To get some information about the performance of quenching media, the hardness at several points across the section of a cylindrical test-piece of one type of steel is usually determined. The result of this test, however, holds only for similar cross sections and allows no conclusions to be made about the behaviour at different dimensions. As will be shown, a quenching medium may have a strong action on large diameters and a mild action on small diameters and vice versa. The same holds when quenching media are examined by measurements of the cooling speed for one sample only. These methods have the disadvantage that the results of different investigators can rarely be compared, due to the differences in heat conductivity, specific heat, density, and surface condition of the test-pieces. A method frequently used, free from these defects has been described by A. Rose[1]: A silver sphere, 20 mm. ($\frac{3}{4}$ ins.) diameter, is quenched in the medium to be investigated and the cooling speed at the core, in relation to the temperature, is measured. To obtain figures for the quenching capacity which are independent of the dimensions of the test body, heat transfer coefficients are frequently calculated from the curves obtained. Fig. 1 shows the quenching action of water at 20 deg. C. (68 deg. F.) plotted against the heat transfer coefficient. It is small in the range of vapour layer formation, reaches a maximum during the boiling period, and is again small at low temperatures where the heat losses are mainly due to convection. There are only a few investigations published concerning the relation between the characteristic of a quenching medium obtained with a silver sphere of comparatively small diameter and its behaviour in practice; particularly regarding the heat treatment of large sections.

Fig. 2 shows the influence of the diameter of a cylindrical test-piece and the quenching action on the cooling speed of the core at 600 deg. C. (1112 deg. F.). The hardening temperature was 850 deg. C. (1562 deg. F.) and the temperature of the quenching medium was 30 deg. C. (86 deg. F.). The cores of bulky articles cool slowly, even with very abrupt acting media. With increasing quench action the cooling speed reaches a limit. It is reached with a medium which immediately brings the surface of the test-piece down to its own temperature.

The cooling speed increases with the temperature gradient between the surface and the core. Considerable temperature differences may occur at comparatively small cross sections. Hardening in oil with a quench action of 1000 Kcal/m² h. deg. C. (205 B.T.U./ft.² h. deg. F.) the surface of a 20 mm. ($\frac{3}{4}$ ins.) diameter test-piece reached 490 deg. C. (914 deg. F.) while the core was at 600 deg. C. (1112 deg. F.); a 100 mm. (4 ins.) diameter test-piece under the same conditions had a surface temperature of 270 deg. C. (518 deg. F.). Quenching with water having a heat transfer coefficient of 4000 Kcal/m² h. deg. C. (820 B.T.U./ft² h. deg. F.) the surface temperatures of a 20 mm. ($\frac{3}{4}$ ins.) diameter and 100 mm. (4 ins.) diameter test-pieces were 280 deg. C. (536 deg. F.) and 110 deg. C. (230 deg. F.) respectively.

Big temperature stresses are thus produced putting the outer layers in tension and the inner ones in compression. Under these tri-axial stress conditions, the elastic stresses may be appreciably above the yield point of uni-axial stress[2]. During the tempering of the steel these elastic stresses are almost completely removed. If, however, the stresses created by quenching are beyond the yield point which corresponds with the existing state of stress and the instantaneous temperature, distortions will occur. If these are obstructed, the stresses will continue to rise until cracks appear.

The danger of cracking on account of large temperature differences is particularly great with large cross sections. These are necessary, however, for high

(1) A. Rose: Mitt. K.-Wilhelms.-Inst. Eisenforschg. 19 (1937), pp. 199-207.

(2) G. Wassermann: Mitt. K.-Wilh.-Inst. Eisenforschung. 17 (1935), p. 167.

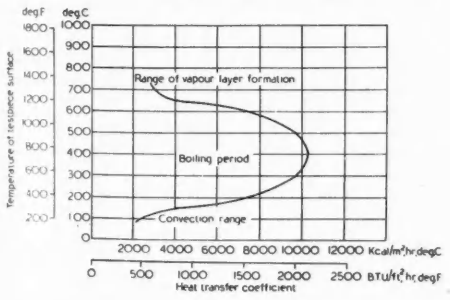


Fig. 1

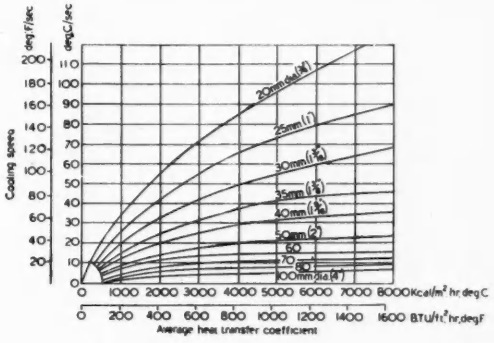


Fig. 2

cooling speeds of the core, and it is therefore impossible in these cases to combine strong quenching action with freedom from internal stress. The surface temperatures at diameters larger than 60 mm. (2½ ins.) and quenching media stronger than the usual mineral oils are found to be less than 300 deg. C. (572 deg. F.), while the core temperature is still in the region of high transformation speeds. (See Fig. 2). With small dimensions the range of strong quenching action may be limited to a small temperature interval on account of the small temperature difference between core and surface. At low temperatures the heat transfer coefficient should be small. Thus, temperature differences can be equalized somewhat after the crossing of the critical region of pearlite transformation, thereby considerably reducing internal stresses.

Fig. 3 shows the change in quenching effect of different media plotted against the test-piece diameter. This was obtained by (a) calculating the cooling speed in the core of a cylindrical test-piece, assuming an average heat transfer coefficient, and (b) by measuring the cooling speed at 600 deg. C. (1112 deg. F.) in the core during quenching in water, 10 per cent caustic soda or mineral oil. It is seen that the quenching action varies with the cross section (Fig. 3). It is severe with small diameters and decreases asymptotically to a lower limit as the diameter increases.

Fig. 4 shows the quenching effect of several media based on the characteristics published in the literature (1), (3). It is interesting to note, that for small dimensions cold water shows a high quenching effect, while water at 60 deg. C. (140 deg. F.) reacts only mildly. At dimensions over 40 mm. (1-9/16 ins.) diameter the quenching action of warm water increases quickly and between 50 and 100 mm. (2 to 4 ins.) diameter it is stronger than that of cold water. With very bulky objects cold water is again somewhat more effective.

A surprising result is that, for certain ranges warm water quenches more strongly than cold water. This has been proved on ·4 per cent C., ·8 per cent Mn-steel. Cylindrical test-pieces of 70 mm. (2¾ ins. approx.) diameter have been quenches under similar conditions in cold and warm water and the hardness has been measured along a diameter of the cross section. The cold water had a temperature of 22 deg. C. (72 deg. F.) and the hot water 55 deg. C. (131 deg. F.). The test-piece quenched in warm water showed, in fact, the greater core hardness. The transition range between good and bad quenching action of warm and cold water is between 30 and 60 mm. (1¼ to 2⅜ ins.) diameter. Tests confirmed the existence of this transition range.

The motion of the water bath in the experiments with the silver sphere, which gave the basic figures for calculations, was at a rate of 30 cm./sec. (1 ft./sec. approx). With higher speeds of the water bath the transition range between good and bad quenching action is shifted to smaller cross sections. At the same time the heat transfer coefficients are increased.

According to these results, heating up the water bath is to be avoided for parts up to 60 mm. (2⅜ ins.) diameter if a strong quenching effect is required. Between 30 and 60 mm. (1-3/16 and 3⅜ ins.) diameter results may be inconsistent. Between 60 and 90 mm. (2⅜ and 4 ins.) diameter a slight improvement may be obtained by using warm water. For still larger dimensions the quenching action of warm and cold water is practically the same; on account of the internal stresses, however, warm water is preferable. The temperature of the water should not exceed 60 deg. C. (140 deg. F.) because the quenching action of water falls quickly with high temperatures.[4].

The quenching action of dilute caustic soda is stronger than that of water, particularly with parts of small dimensions. (See Fig. 4.) This agrees with experience and holds also for lime water which is somewhat weaker than caustic soda.

The quantative information about the quenching action obtained with a silver sphere is higher than that obtained with steel test-pieces, in spite of equal flowing speeds in the quenching baths; a comparison of Figs. 3 and 4 will show this. It is due presumably to the formation of scale on the steel specimens which adversely affects the quenching action. Different flow conditions may also affect experiments with small silver spheres[4]. The trend, however, of the curves appears to be the same in Figs. 3 and 4, and the results of silver sphere experiments will therefore give much information for practical purposes in comparing investigations of different quenching media. The opinion of H. Krainer and K. Swoboda, and also of H. Peter has been confirmed by experiment, namely, that in the hardening of large cross sections, the quenching effect at low temperatures is of importance, whilst for thin sections, quenching should be strongest at high temperatures. A new type of test which has been made makes it possible to calculate the quenching effect of a quenching medium for different cross sections.

All these considerations refer to a cooling speed in the core of the work-piece at 600 deg. C. (1112 deg. F.) and are therefore valid only for steels with high transformation speeds in the pearlite range. There are, however, numerous others, particularly high alloy steels, which tend to transform quicker in the intermediate stage than in the pearlite stage. Most suitable for these cases are quenching media which have strong quenching action at low temperatures, say, below 450 deg. C. (842 deg. F.) with small and below 300 deg. C. (572 deg. F.) with large dimensions. According to Fig. 4 these show high quenching effect at large cross sections.

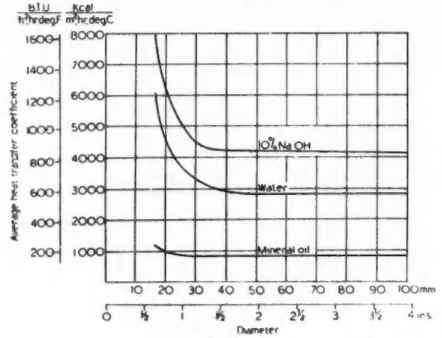


Fig. 3

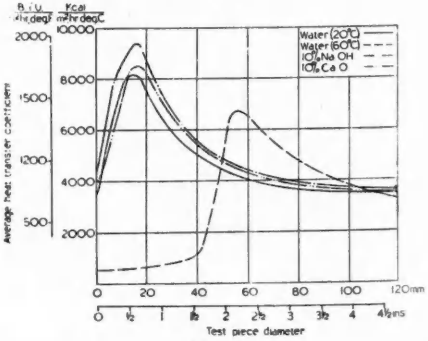


Fig. 4

(3) H. Krainer and K. Swoboda: Arch. Eisenhuettenw. 17 (1943/44). pp. 163/69.

(4) Discussion with reference to (3).

PREFABRICATED METAL ROOFINGS.

(From *L'Ossature Metallique*, Vol. 10, Nos. 9-10, September-October, 1945, pp. 180-182, 5 illustrations).

ETABLISSEMENTS PAINDAVOINE FRÈRES, Lille, have just perfected a method of making prefabricated roofs, with sections easily transportable in units weighing less than 400 kg. (8 cwts.).

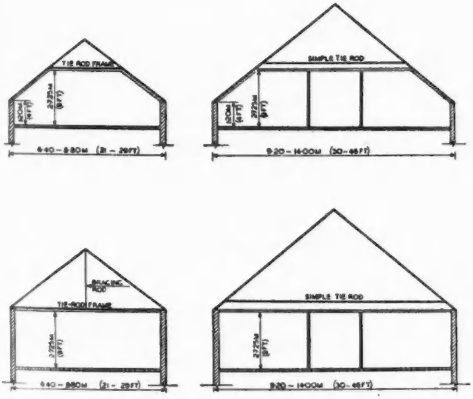
The object sought and attained was to reduce to the absolute minimum the number of separate elements required to make a roof (such as trusses, purlins, rafters, battens, wind bracings, etc.). The minimum attained has been two elements namely, ridging and tie-beams, the covering being of tiles as for an ordinary roof.

It was essential that the units should be easy of transport and easy to handle both for weight and size. For carriage by rail or lorry the width should not exceed 3 metres (about 10 feet), the length should be between 4·1 and 9 metres (13 to 30 feet). As for weight, each unit weighs between 250 and 400 kgs. (5 to 8 cwts.) which can be handled by 4 or 6 men.

Figs. 1 and 2 show the two types of construction of a symmetrical roof based on "A" or △ style, with or without a false ceiling.

The roof is easily fixed up by the assembling of 3 units (2 ridging and 1 tie), forming a roofing unit 10 feet wide. Bolting several of these units together gives the required width of roof.

Fig. 3 shows the method of assembling an "A" style roof by means of a fixing trestle. This shows the simplicity of the method, with no special tools needed, and it can be done either at roof level or on the ground, in which case the assembled roof is hauled up to the required height. This last method is only recommended when the number of units exceeds 3, that is, for buildings with more than 30 feet frontage.



Figs. 1 and 2. **"A" and *Delta* type roofs with and without false roof.**

RIDGES.

The ridge (Fig. 4) which is a complete unit prefabricated in the shop, can be split up into several essential parts : frame, lattices, sill, beams and ridge beam.

The frame is made of three rafters of tubular section, two end and one intermediate. These sections are made either by welding two angle irons together or of welded tube bent on a special machine. The two end rafters have at *R* the fixing bolt to join them to the tie-rod, this attachment being fitted at the base for a △ roof and at some point up the rafter for an "A" roof. Holes are made to allow of bolting to the adjacent ridge sections.

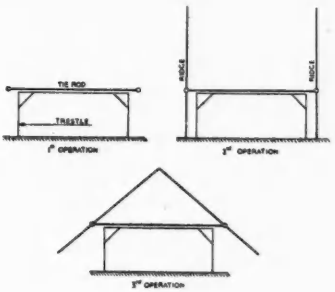


Fig. 3. **Assembly of an "A" type roof element by means of a trestle.**

To the rafters, battens are welded with a free span of 1·5 m. (60 ins.). These battens are made of angle iron 30 × 30 × 3 mm. (1·$\frac{3}{16}$ ins. × 1·$\frac{3}{16}$ ins. × $\frac{1}{8}$ ins.) spaced at 238 mm. (9$\frac{1}{2}$ ins.) and support the tiles to a weight of 50 kg./m.² (10 lb./ft.²) It is essential to space the battens correctly as the next section of roof must have its battens exactly in line. Assembly templates allow of this being done automatically.

The sill rafter serves two purposes ; it serves as a support for the roof on the head of the wall and also spreads the load of the centre rafter (which has no tie-rod) on to the two end rafters. It is made of angle iron 2 to 3 mm. thick ($\frac{5}{64}$ in. to $\frac{1}{8}$ in.) bent to the required angle. The horizontal face is drilled with oval holes to allow of the sill being fixed on to the top of the wall. The sill is therefore like a small triangular caisson with access to the inside in order to fit bolts and to tighten up nuts.

The ridge purlin also serves two purposes, namely, to join the two rafters together and to spread the load of the centre rafter on to the two end rafters. It is made of two parts (one for each rafter) joined by bolts at *A* and *B*. The half-beam *AOB* is welded to the rafters cut perpendicular to their axis and angle *AOB* is therefore 90 degrees. Consequently the ridge purlin is symmetrical only to its vertical axis.

TIE RODS.

For buildings between 6·4 m. and 8·8 m. (21 to 29 feet) deep, the tie rod can act as a false roof. It is then made as a frame 3 m. (10 feet) wide with 4 articulated joints (*R*) stiffened by traverses and able to support the weight of the ceiling (see Fig. 5). A wooden lining fixed to these traverses will allow of sheets of Isorel (wall board) being affixed. A works maintenance carpenter would be quite able to deal with this work (sawing and fixing).

Where a false roof is not desirable, this frame is replaced by two draw bars to each roof section.

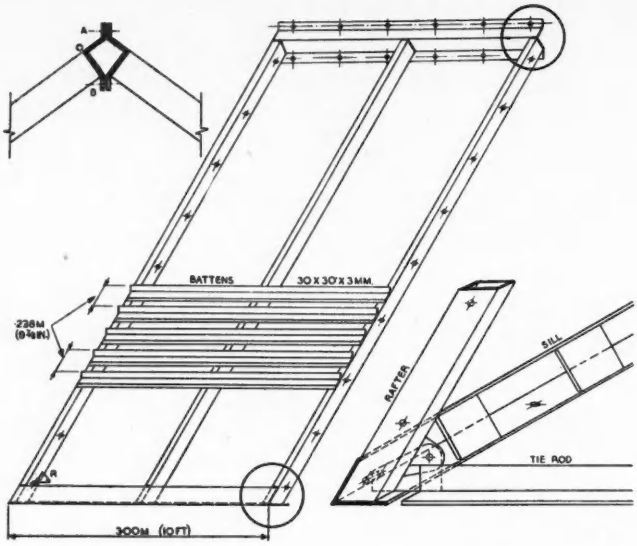


Fig. 4. **Details of a ridge element, completely prefabricated**

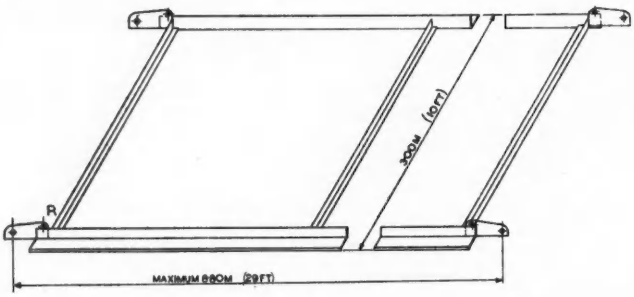


Fig. 5. **Tie-rod frame provided with four holes for articulated joints.**

ACCESSORIES.

(a) BRACING RODS. To limit the deflection of the tie rods, especially when they support a false roof, it is advisable to fix bracing rods at the centre of the tie-rod span, fastened to the ridge purlin. This does not cause any difficulty in manufacture, as these rods can be made, for example, of round iron bars.

(b) WALL CAP. This is supplied either fixed to the tie rod or detached. In the first case, it is sealed on to the wall with the tie rod, in the second case, the cap is first sealed into the wall and the tie rod is then fixed to it.

Cost of these types of Roofing.

(a) METAL FRAMEWORK.

Steel (rafters, battens, bolts) ..	36 kg./m.² (7·4 lb./ft.²)
Anti-rust paint ..	0·34 kg./m.²(0·07 lb./ft.²)
Welding	3 m./m.² (·92 ft./ft.²)

(b) FALSE ROOF.

Wood ..	0·008m.³/m.² (0·022 ft³/ft.²)
Isorel panels ..	1·2 m.³/m.² (1·2 ft.²/ft.²)

(c) TIME FOR ERECTION ON SITE .. .. .. 30 per cent gain.

CONCLUSIONS.

Metal framework of rafters and ties, as described above, for a symmetrical roof with two slopes, is of interest for the following reasons :—

1. It allows of much more intensive prefabrication than with ordinary roofs with their trusses, purlins, rafters and battens, since the components for assembly on the job have been reduced to two.

2. This intensive prefabrication has been made possible by the use of welding. The work in the shop may be a little more, but the saving of time on site will be much larger without calling for any specialized workmanship.

3. Erection can be done so quickly that a building of this type can very quickly be roofed in and so allow the other tradesmen to get on with their job sheltered from bad weather.

4. Attics are quickly put into condition for living in by the use of wall-board panels, which are clean and do not leave any rafters or roof joints exposed.

5. Anchorage of the roof on the walls is simple. The wall heading can be laid on by a mason before the fixing on of the roof proper. Anchorage is still simpler if the whole of the building is of metal construction.

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(Note - All figures in parts per 100,000.)

Plant		No. 1		No. 2		No. 3	
Water		Crude	Treated	Crude	Treated	Crude	Treated
Cations							
Calcium	Ca	3.2	–	9.4	–	10.7	–
Magnesium	Mg	0.8	–	0.36	–	1.09	–
Sodium	Na	0.46	0.23	1.0	0.31	1.66	0.44
Total		4.46	0.23	10.76	0.31	13.45	0.44
Anions							
Carbonate	CO_3	4.2	0.24	12.4	0.29	10.5	0.57
Chloride	Cl	1.8	0.06	2.5	0.12	2.84	0.30
Sulphate	SO_4	1.35	–	3.48	0.03	11.95	–
Nitrate	NO_3	–	–	–	–	1.15	–
Total		7.35	0.30	18.38	0.44	26.44	0.87
Total ions in solution		11.81	0.53	29.14	0.75	39.89	1.31
COST per 1000 gallons		5.22d		9.83d		16.5d	

The table shows the composition of some types of water before and after treatment by Permutit's "Deminrolit" Process. Water similar to a distillate is produced by this process at a fraction of the cost. Where distilled water was too expensive you can afford "Deminrolit" water. The process has been in practical use in Great Britain for over 7 years. Write for technical publication "Distilled Water without Distillation" to

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CLASSIFIED ABSTRACTS

Numerous important articles which, for lack of space, cannot be published in full in our main editorial columns, are regularly abstracted in this section. Subscribers may obtain photostat copies of all original articles at cost.

ACOUSTICS

The Measurement of Reverberation.

By W. TAK. (From *Philips Technical Review, Holland*, Vol. 8, No. 3, March, 1946, pp. 82-88, 12 illustrations.)

IN a room where sound is produced the intensity does not immediately decrease to zero after the source of sound has ceased to act. Depending on the circumstances, a certain time is necessary before the sound dies out. This phenomenon of reverberation has great influence, not only on the intensity of the sound, but also on the intelligibility of speech and the quality of music, and is therefore important in judging the acoustics of a room.

In this article several theoretical considerations about reverberation in rooms and auditoria are discussed. The phenomenon of reverberation is considered as the sum of a number of damped characteristic vibrations. Due to interference, fluctuations are superposed upon the mainly exponential variation. The variation in intensity depends upon the shape and dimensions of the room, upon the distribution and the properties of the absorption material, upon the position of the observer, upon the position of the source of sound and upon the frequency spectrum of the sound produced, but when these factors remain constant it is completely reproducible.

Several principles are indicated according to which apparatus can be constructed which makes it possible to study the variation in intensity during the reverberation and to characterize it by one or more parameters.

BEARINGS

The Theory of the Single-Groove Ball Bearing.

(From *Die Kugellager Zeitschrift, Switzerland*, No. 3, 1944, pp. 39-50, 12 illustrations, printed January, 1946).

THE static distribution of the external bearing loads over the balls in anti-friction bearings depends on the displacements at the points of contact of all loaded balls. There are theories on this load distribution based on the assumption of no deformation of the races at stations other than the points of contact with the balls. However, the theories are valid for constant angular loads and parallel displacement of the races relative to each other only.

The present paper gives a graphical method for the determination of the load distribution in the bearing by assuming that the relative translational and angular displacements of the races are known.

Analytical treatment is applied to the case for which the angle of loading changes with the external load, but remains constant for all the balls. This can be used with sufficient approximation in the case of a shaft supported in two bearings so that there is little or no angular displacement under load.

Based on the aforementioned theory, diagrams are shown where the displacement of the races is plotted against varying magnitude and direction of the external load. Further, equations are given for the equivalent static and dynamic loading. The calculations apply, strictly speaking, to *bearings without clearance* only. The effect of clearance is assessed by a method of approximation. As for bearings with clearance, the axial load carrying capacity is somewhat higher, the expressions given for equivalent loadings can be applied also to bearings with clearance.

ELECTRIC CONTROL AND SIGNALLING

Remote and Automatic Control of Electrical Installations.

By E. TAVERNIER (From *La Houille Blanche, France*, No. 2, March, 1946, pp. 103-116, 16 illustrations.)

RECENT technical progress had made possible simply and reliably equipped automatic and remotely controlled electrical installations with low running costs and, especially for small and medium sub-stations, quick amortisation of capital expenditure. The electrical lay-out of these installations, however, is complicated as normal functioning and behaviour in case of unforeseen accidents must be anticipated. General principles can hardly apply, each case must be considered on its own merits.

Protective and safety devices must comprise normal safety precautions as well as warning signals and fault indications for " Main Control."

Remote control installations include remote position indicating and warning signals, remote control lines and, often, remote measuring circuits. As auxiliary pilot lines are expensive if extended over several hundred yards, solutions should contain a minimum number of pilot wires, or no pilot wires at all.

Examples are given of pilot wire circuits with sensitive relays, with selective relays acting on the principle of automatic telephone exchanges, and with multiple synchronized relays. Finally, electric A.C. impulses at sound frequencies can control sub-stations over pilot wires or, by carrier current, over the high tension net proper, each control and sub-station having receiving and transmitting sets for these signals. Measurement circuits are mentioned separately.

Examples of automatic sub-stations are automatic feeder sub-stations which isolate faulty bus sections and switch feeder lines on to healthy sections, automatic transformer sub-stations which regulate the number of transformer units in service according to the electric load required, and automatic power stations which start, regulate, and stop generating machinery according to e.g. water level, supply required, or a predetermined daily supply programme.

Semi-automatic installations finally perform certain groups of operations automatically while others are manually or remotely controlled. Thus, putting under tension the H.T. line from sub-station to " Main Control " may initiate automatic starting up of an entire generating sub-station.

ELECTRIC FURNACES

Electronic High Frequency Furnaces.

By A. de SAINT-ANDRIEU. (From *Fonderie, France*, No. 4, April, 1946, pp. 143-155, 5 illustrations.)

EXISTING types of electric furnaces are surveyed and the principles of electronic furnaces explained. A high frequency solenoid is arranged round an acid crucible and current from an electronic valve supplied to the oscillator circuit. The frequency can be adjusted by varying the capacitance of the oscillator circuit. By reducing the frequency as the melt proceeds, the valve load is maintained, the heat distribution equalized throughout the charge and fusion accelerated.

The electronic furnace offers great speed of melting,

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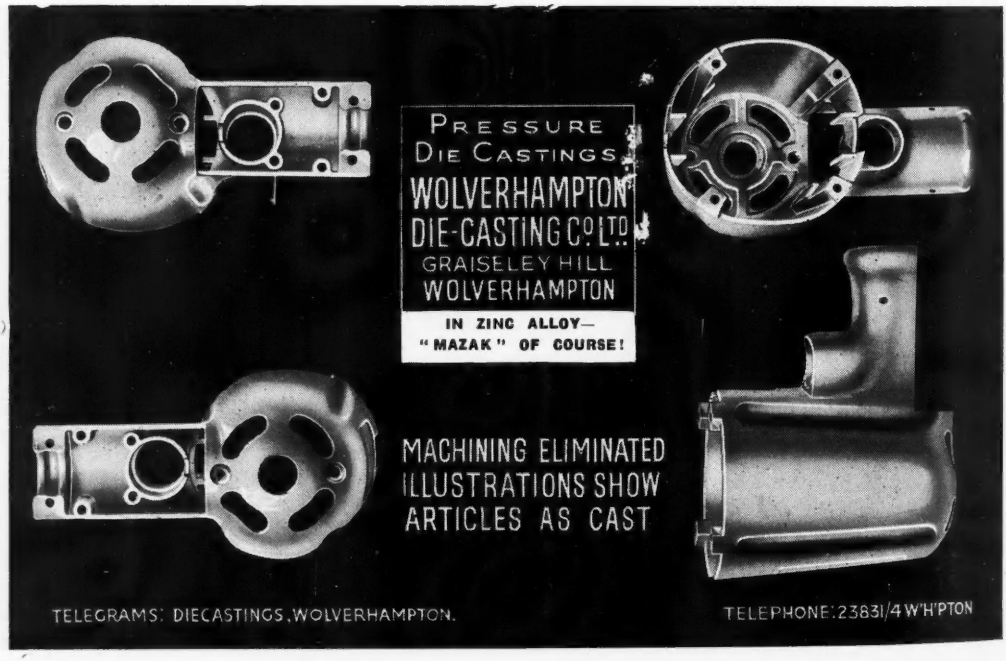

Electric Furnaces—*continued.*

flexibility of operation and uniformity of product. Currents in the liquid metal are much reduced, silicon pick-up and fire losses negligible. Unwanted carburisation cannot occur. Priming is not necessary. The installation is static, practically noiseless, shows little wear and can easily be adapted for melting in vacuo or gas atmosphere. However, production is expensive and output limited. Only expensive metals in small quantities can be molten economically.

One of the most powerful installation (250 Kw), in operation at Paris, is described in detail. Two tilting crucibles made from "Nemours sand" with addition of fritter material and insulated by asbestos sheets from the surrounding solenoids are worked in rotation. Incoming high tension voltage is reduced in a two-tank Scott transformer, feeding current to the valve and auxiliaries. Two H.T. transformers lead to twelve mercury vapour rectifiers type DCG 5/30 and thence at 20 kV to the two standard broadcasting transmitter valves type TA 20/250. 72 condensers with selector switch, the crucible solenoids, and H.F. transformers form the oscillator circuits fed from the valve anodes.

Operation is simple and controlled entirely from a switchboard; interlocking and safety devices are provided. The starting frequency is 17 kilocycles per second, reduced to 13, 9, and 7 kc/sec. as fusion of the charge proceeds.

The nominal crucible charge is 110 lbs. of steel, melting time 12 minutes average, the maximum charge 286 lbs. (32 minutes). The crucible outlasts approx. 100 steel charges of 175 lbs. Electricity consumption is ·57 kWh per lb. of molten steel.

Mention is also made of smaller installations and laboratory furnaces.

ELECTRIC MACHINERY

Temperature Rise of Water-cooled Power Transformers.

By J. R. MEADOR. (From *General Electric Review, U.S.A.*, Vol. 49, No. 4, April, 1946, pp. 55-59, 8 illustrations.)

THE purpose of this article is to show how the transformer top-oil temperature varies when the load, water rate, and ingoing water temperature are changed and to give curves for estimating the effect on the winding hot-spot temperature. It contains no new test data on winding hot-spot temperatures. It appears, however, that published information on self-cooled transformers can be used to estimate the hot-spot temperature in water cooled transformers. Analysis of the oil temperature rise shows that consideration of the effect of viscosity gives new data on the performance of the transformers as affected by load, water rate, and water temperature.

The top-oil temperature of water cooled transformers depends on the amount of cooling oil, the transformer losses, the water rate and the ingoing water temperature. As the flow of oil through the windings of a water-cooled transformer is very similar to that in a self-cooled transformer having external radiators, the same general equations for winding rise over oil can be used. The following general conclusions are reached assuming that the radiation and convection losses —which can be properly evaluated for each specific case—are negligible:

1. Oil temperature rise over ingoing water temperature is not a simple function of the loss dissipated. However, oil rise varies approximately as (loss) $^{0.65}$.

2. When the water rate is changed, the oil temperature rise varies 40 per cent as much as the change in water temperature rise.

3. When the water temperature is lowered, the oil temperature rise over ingoing water increases 0·75 per cent for each degree the ingoing water temperature is below 25 deg. C.

4. In a typical transformer the load can be increased 0·8 per cent for each degree the ingoing water temperature is below 25 deg. C.

GAS TURBINES

Coal-Burning Gas Turbine.

By J. I. YELLOTT. (From *Mechanical Engineering, U.S.A.*, Vol. 68, No. 5, May, 1946, pp. 465-66. 2 illustrations.)

THE virtually inexhaustible coal reserves of the United States and the high theoretical thermal efficiency of the gas turbine have encouraged some of the American railroads and Bituminous Coal Research, Incorporated, to sponsor research on the application of coal as a fuel for the gas turbine.

Three major problems impede the application of coal as a fuel for the gas turbine of a locomotive. The first of these is the preparation of the coal for combustion. Coal must be transported from the bunker, pulverised to the smallest practical particle size, and fed to the combustor at a controlled rate.

Space limitations impose the second major problem, the magnitude of which is emphasized by the fact that there is today no pulverised-coal-burning locomotive in operation. Finally, the problem of fly ash in the products of combustion must be solved before the coal-burning gas turbine can be considered a practical prime mover.

The Locomotive Development Committee propose a coal-handling system designed to convey coal from the bunker by a special type of screw feeder. Rate of coal flow is accomplished simply by varying the speed of the driving device. By the introduction of waste hot air into the trough along which the coal moves, drying is started as soon as the coal leaves the bunker.

The first step in coal preparation for the "coal atomizer" used by the Locomotive Development Committee involves crushing the coal to reduce it to a minus-10-mesh size by means of a simple hammermill. The coal is then further dried and conveyed to the pressure tank from which it is fed to the coal atomizer, which operates on the continuous-explosion principle. The crushed coal in the pulverizer tank is subjected to high air pressure and the pores of the coal particles become filled with the compressed air. By causing the coal to pass through a nozzle, where the pressure falls instantaneously, the particles are shattered by the sudden release of the entrapped air. If the feed particles are smaller than one third of the throat diameter of the nozzle, clogging will not occur. About one pound of air per pound of coal is necessary for pulverization to such a fineness that more than 50 per cent of the product will pass a 200-mesh screen. By adding a simple attrition device, called a "cyclonizer," the fineness can be increased until 80 per cent passes through a 325-mesh screen.

INTERNAL COMBUSTION ENGINES

Low Tension Ignition and Ignition By Means of an Injection of Ignition Oil.

(From C.I.O.S. REPORT, Item No. 19, File No. XXIX-53/54.)

AT Junkers' in Dessau experiments have been conducted to obviate electrical ignition troubles which were progressively increasing as the engine outputs were boosted, and higher altitudes encountered.

Aircraft engines, using normal high tension ignition operating at about 10-kv, can be employed up to heights of about 12-km. At greater heights, engine trouble develops due to the spark jumping the insulation in the

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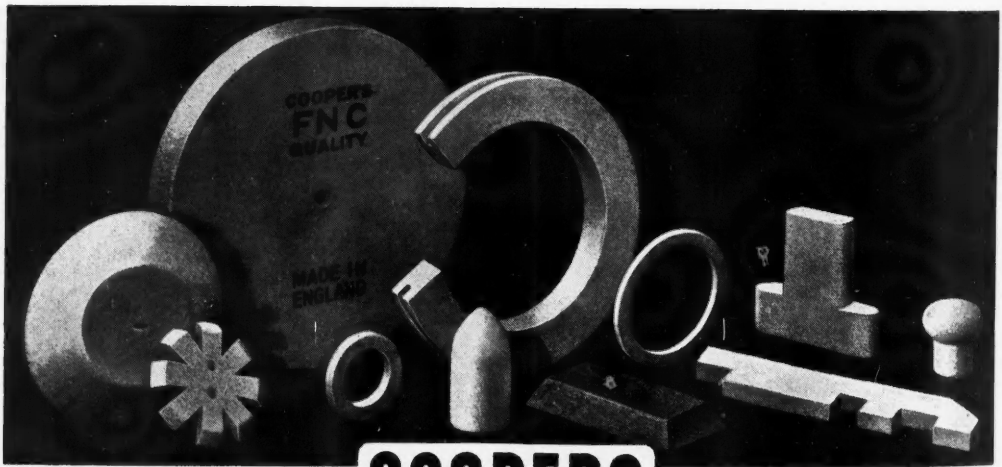

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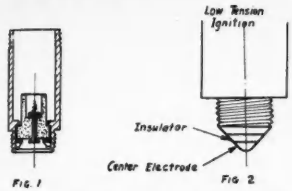


FIG. 1 FIG. 2

plug itself, or in the high tension leads due to decomposition of the cable insulation and the higher operating tensions resulting from burned spark plugs.

For this reason, it was desired to develop an ignition system which eliminated the root of these failures. Two courses of pursuit were followed each described in a separate report, namely, (1) Low Tension Ignition and (2) Ignition by means of an injection of " Ignition Oil."

(1) *Low Tension Ignition.*

Surface discharge plugs operating at between 400- and 1000-volts seemed the solution to the above questions. Fig. 1 shows a section through such a plug developed by Siemens. The spark no longer jumps an air gap as in the conventional type of plug but " glides " along the surface of the insulation ceramic.

In another design of plug developed by Beru, the electrodes are constructed in the form of a cone projecting into the combustion chamber, Fig. 2.

The low-tension ignition was brought to a reasonable state of reliability, and with further development work the same degree of reliability should be reached as in high-tension ignition.

(2) *Ignition by Means of an Injection of " Ignition Oil."*

Single cylinder tests were carried out at Junkers' in December, 1944, on a method of ignition employing an injection of "Ignition Oil" which had been developed by I. G. Farbenindustrie. Its specific weight at 20 deg. C is 0·91, calorific value 6900 Kcal/kg, air required for combustion 9·33 kg/kg, cetane value about 180.

A four stroke internal combustion engine employing a cycle lying between Otto and Diesel cycles was developed by the I. G. Farben at Ludwigshafen. This engine had the following characteristics :

1. An easily vaporized fuel is injected into the cylinder during the suction or compression stroke. (Otto cycle).

2. Ignition is produced by injecting a highly inflammable oil into the compressed air/fuel mixture (Diesel cycle).

3. The power output is controlled by altering the amount of fuel injected, the quantity of " Ignition Oil " remaining constant.

Junkers' were interested in the application of this principle to a two-stroke Otto cycle engine. For this purpose single cylinder tests were carried out on a water-cooled unit of the two-stroke Diesel aero engine, Jumo 223. These tests have established that as far as output is concerned, this is the same as with spark ignition. It is of interest that between speeds of 3000 and 4400 r.p.m., using the same fuel ratio, constant torque was obtained. This means that, contrary to spark plug ignition experience, the fuel ratio is still satisfactory at 4400 r.p.m. Thus, the main advantage of this development is that it is independent of the air/fuel ratio, which would enable an engine having simple controls, like the Junkers' aero-Diesel engine, to be developed.

Difficulties were experienced with this engine due to the " thermal sensitivity " when starting from cold in cold atmospheric conditions, when uncertain firing, or failure to start resulted.

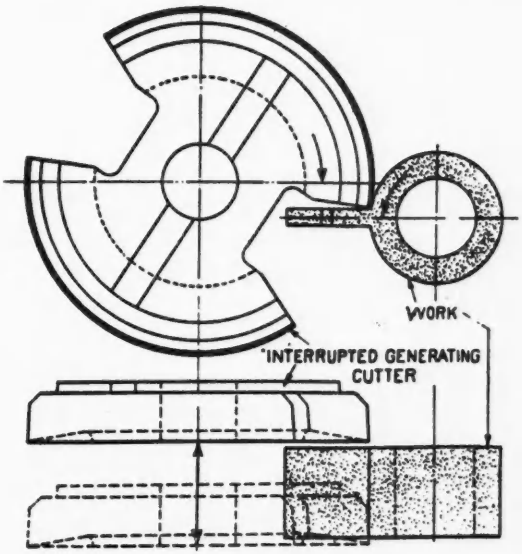
However, the tests carried out were of a limited nature, and improvements should be possible.

MACHINE SHOP PRACTICE

Gear-Shaper Generating.

By R. W. BOLZ. (From *Machine Design, U.S.A.*, Vol. 18, No. 3, March, 1946, pp. 121-128, 22 illustrations).

ALTHOUGH gear-shaper machining is generally considered a special-purpose process primarily adapted to the generating of gears and gear teeth, its overall versatility and ability to produce an ever increasing variety of machine parts, places it among the important mass-production processes. The generation of eccentric, gap, metering, and special type gears by this method, as well as ratchets, clutches, cams, multiple cams, splines, and unusual shapes, presents not only a fascinating but also a highly practical study for machine designers interested in lowering production costs of such special machine parts.



Of great importance in connection with the application of the gear shaper generating principle is the cutting tool used and its method of operation. Reciprocation of the cutting tool makes possible its application to the generating of external and internal surfaces by properly controlled movements of work-piece or tool, or both, and also permits operating the tool in comparatively narrow recesses. It is this combination of tool reciprocation with controlled generating motion which makes the " Fellows Method " so universal in its application to the production of unusual machine parts.

Combining the basic principles of both the common engine lathe and the well known crank shaper, the gear shaper usually allows a selection between several methods of machining, simplifying production problems. Rotational movement as well as position variations can be imparted to the generating tool or to the work and, in some cases, a " conjugate " or mated surface can be used on the cutting tool to generate a desired shape. Often combinations of movements and " conjugate " shapes can be employed to achieve results that would otherwise be extremely difficult or impossible to obtain.

" Interrupted-conjugate " generating can be applied to unusual parts where the progression of cutting must be interrupted. The refrigerator pump piston, shown in the illustration, is typical of a part successfully machined by an interrupted cutter.

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PHYSICS

The Shape of a Flame near the Walls.

By D. A. FRANK-KAMENETZKY. (From *Comptes Rendus* (Doklady) de l'Academie des Sciences de *l'URSS*, 1945, Vol. 46, pp. 232-235, 4 illustrations).

IN burners of the duct type the concept of the fundamental velocity of flame propagation is based upon the assumption that heat transfer takes place only normal to the flame surface. This assumption makes it possible to treat the problem as uni-directional and to compute the velocity of flame propagation. It is obvious that this assumption does not always hold true, as in the immediate vicinity of the wall heat transfer in a direction parallel to the flame surfaces becomes an essential factor. In order to analyse the phenomena taking place under these conditions, it is therefore necessary to develop a multi-dimensional theory of flame propagation. The author shows how the angle at which the flame front approaches the wall may be found. The assumption is made that the temperature, and the temperature gradient in the flame zone remain practically constant, as the latter approaches the wall. This assumption follows naturally from the general theory of flame propagation as set out by J. B. Zeldovich and D. A. Frank-Kamenetzky (*Zhournal Phis. Chim.* Vol. 12, 1938, p. 100) according to which, in view of the marked exponential relationship between reaction rate and temperature, the rate of reaction at temperatures below the maximum flame temperature may be disregarded. Therefore, the region in which the combustion processes take place may be divided into a preheating zone and a reaction zone. In the preheating zone the heat evolved as a result of reaction is disregarded, while in the reaction zone the heat transferred by convection by the gas flow is left out of consideration.

From his findings the author concludes that the flame always approaches a cooled wall at a negative angle. But if the wall is externally heated, or if it liberates heat as a result of catalytic reaction, the flame approaches it at a positive angle.

The report is based upon research carried out by the author at the Zhukovsky Central Aero-Hydrodynamic Institute, Moscow.

POWDER METALLURGY

Powder Metallurgy.

By R. GIRSCHIG. (From *Revue de Metallurgie, France*, Vol. 42, 1945, No. 6, pp. 178-186, No. 7, pp. 218-229, 37 illustrations).

AFTER making some general observations on problems of powder metallurgy, the author discusses the sintering process with particular reference to the manufacture of self-oiling bearings. At the laboratory with which the author is connected, porosity of the sintered product is controlled by the addition of ammonium-carbonate to the iron powder, sintering being carried out in an hydrogen atmosphere. By varying the percentage of ammonium-carbonate the density of the product can be controlled. A powder containing 20 per cent of ammonium carbonate and 80 per cent iron and compressed at 7·3 ton/sq. cm. yields a product of the specific gravity of 4·0 after sintering at 890 deg. C.; while a powder containing 10 per cent ammonium carbonate and treated in identical manner has a specific gravity of 5·0. An iron powder to which no ammonium carbonate has been added has a specific gravity of 7·15 after identical treatment; while an uncompressed iron powder without ammonium carbonate and sintered at 950 deg. C. shows a specific gravity of 3·5.

In the case of bearings of sintered bronze, the powder passes through a transitory liquid phase during the sintering process. Homogeneity is therefore rarely achieved, as evidenced by the presence of copper particles embedded in a matrix of α and δ bronze. No such liquid phase occurs in the sintering of iron powder in a hydrogen atmosphere at temperatures ranging from 850 to 1200 deg. C. The mechanical strength of sintered iron powder can be increased by cementation. In the case of powders of small porosity, cementation is similar to that of the solid metal, but the speed of cementation is slower owing to the porosity of the material. In a bearing of high porosity cementation extends to the entire mass of the metal in a uniform manner. Coalescence of pearlite can be carried out by proper heat treatment; and it is thus possible to obtain a product in which globular particles of very hard dementite are distributed in a soft matrix of ferrite. This provides a bearing of excellent service properties. The article also contains a detailed description of a machine developed by the author for the operational testing of sintered bearings.

RADIO ENGINEERING

"Application of Indirect Ray Propagation Theory to the Calculation of Frequencies for Radio Links in the 10 Metre Band."

By R. AUBERT. (From *Bulletin de la Société Française des Électriciens, France*, No. 57, March, 1946, pp. 111-128, 26 illustrations.)

FUNDAMENTAL formulæ for losses by reflection and absorption in the Ionosphere are quoted, and the existence of a "critical wavelength," and a "maximum usable frequency" (M.U.F.) is established.

Small scale graphs are given, for latitudes 40 deg.-50 deg. North, of the "equivalent heights" of the E, F_1 and F_2 layers for the four seasons and for corresponding "critical frequencies." For actual use the monthly predictions in the Proc. I.R.E. are recommended.

The wave may be reflected, at low angles of emission, by the E layer, instead of by the F layer, thus giving shorter range. Curves connect frequency in use with minimum angle of departure for penetration of the E layer. A wave reflected by the F layer suffers losses by reflection there, which decrease with increase of wavelength, and also by absorption in the E layer but these increase with wavelength. The frequency giving minimum *total* losses must be determined. This involves

(i) determination of the trajectory (curves are given).
(ii) determination of the corresponding M.U.F.
(iii) calculation of reflection losses at the F layer.
(iv) calculation of absorption losses in the E layer.
(v) determination of the field strength, and signal-to-noise ratio, at the receiver.

The author shows how to determine the M.U.F. from monthly predictions, but as these are seldom available he shows how a map, on "Mercator's Projection," of M.U.F.'s for mean seasonal conditions over the whole globe, may be used instead, though with less accuracy. Specimen maps are included.

Reflection losses in *db* are graphed against the ratio :—frequency used/M.U.F. Absorption losses in *db* per 1000 km are graphed in terms of the Sun's elevation, which can be found from another set of curves.

On subtracting these losses from the field strength given by Hertz's formula

$$E = 3 \cdot 10^5 \sqrt{W} / D \quad \mu V/\text{metre}.$$

where W = kilowatts radiated
D = distance in kilometres
the resultant field is obtained.

Finally, a day and night frequency are selected for a Paris—New York link on the basis of calculations for conditions at 3 hourly intervals. The signal-to-noise ratio is determined, and agrees well with actual observations.

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NEWS OF THE MONTH

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

PERSONAL

Mr. John C. Brown has been appointed Secretary and Accountant to the Pitter Gauge & Precision Tool Co., Ltd.

Mr. R. Catlow has been appointed Managing Director of Exors. of James Mills, Ltd., Bredbury, Woodley, near Stockport.

Mr. Horace W. Clarke has been elected President of the British Non-Ferrous Metals Federation. **Mr. W. J. Terry, Mr. W. H. Henman,** and **Mr. H. E. Jackson** have been elected Vice-Presidents.

Dr. C. E. Homer has been appointed to the metallurgical staff of the research department of Tube Investments, Ltd.

Aviation Developments Ltd., has formed a subsidiary company in the U.S.A., to be known as Aviation Developments Incorporated. **Mr. Frank Lanes** has been appointed President of the new company.

Dr. J. L. M. Morrison has been appointed to the Chair of Mechanical Engineering, University of Bristol.

The L. N. E. R. has appointed **Mr. A. H. Peppercorn,** O.B.E., M.I.Mech.E., to the post of Chief Mechanical Engineer, in succession to **Mr. Edward Thompson** who retired on 30th June.

The Managing Director of the new E. M. I. Company—E. M. I. Suppliers, Ltd., is **Mr. A. Carrick Smith,** B Sc., A.C.G.I., A.M.Inst.C.E., who, until the formation of the new Company, was a joint General Manager of the Gramophone Co., Ltd.

Professor A. M. Tyndall has been elected President of the Institute of Physics.

Mr. G. Stuart Wood and **Mr. Rawson F. Stagg** have been appointed local Directors of Thos. W. Ward, Ltd., Albion Works, Sheffield.

NEW TRADE LITERATURE

A. C. Voltage Stabiliser.—The Westinghouse Brake & Signal Co. Ltd., Chippenham, Wilts., have published a booklet called the "Stabilistor" which describes the Westinghouse System of stabilising A.C. supply voltage for energising many types of mains-operated apparatus. The system operates on the principle of magnetic saturation and a special circuit has been evolved to provide an undistorted output voltage wave over a wide range of load, whilst the output is held within fine limits in spite of simultaneous variations in both input and load. A special voltage and frequency compensated "Stabilistor" type 'B' for use at constant load, which overcomes variations of output with change of supply frequency is also described in the booklet.

Electric Hoists.—A booklet has been issued by C. E. Reed & Co. Ltd., Cart Lane, Bristol, 1. which illustrates and gives dimensional data of their range of electric hoists. These hoists are made in a variety of loading capacities, lifting speeds, and heights, for use indoor and outdoor. Special features are rope winding guides and cable winding drums.

Hi-Shear Stop Pins.—The latest development of Simmonds Accessories Ltd., Brentford, London, is illustrated in a leaflet dealing with Hi-Shear Stop Pins. These pins consist of two parts, a pin made from alloy steel of 55 tons p.s.i. tensile, and a collar of anodised aluminium alloy. The end of the pin is rounded and has a cannelure over which the collar is placed and swaged when in position.

The pins are claimed to be as strong as a bolt and have proved to be an asset in aircraft construction.

Garage Equipment.—A new publication No. 624, just issued by Tangyes Ltd., Cornwall Works, Smethwick, Birmingham, illustrates and describes Vertical Washing Pumps, and Hydraulic Sleeving and General Purpose Garage Presses.

Messrs. Tangye have also announced the re-opening of a branch office at 5, Cross Street, Manchester.

Simpem Electrode Holder.—The Quasi-Arc Company Limited have issued a Circular No. T.C. 641 describing this holder, for which they hold the exclusive selling rights

This electrode holder is specially designed for use in shipyards and for site welding. It is suitable for welding with electrodes up to 6 s. w. g., that is, for current up to about 250 amperes.

The electrode grip operates on a novel principle ensuring a firm grip on the electrode with good electrical contact and quick release of the stub end.

The holder is of simple steel construction and gives a positive grip to the electrode. A special feature is the detachable taper plug and socket which form one handle of the holder and enables the welder to disconnect the holder body from the cable, leaving the end of the cable still well insulated; the holder thus conforms with Home Office recommendations for electrode holders for use in enclosed steel constructions.

Photo-Electric Cells.—The "Cintel" photoelectric cells, made by Cinema-Television Ltd., Lower Sydenham, London, are described in a new brochure just issued.

The cells are all of the emission type as distinct from barrier layer and selenium cells. They are manufactured in a variety of types which differ in the following three essential properties :-

1. Spectral or colour sensitivity.
2. Vacuum and gas-filled photocells.
3. Overall and cathode dimensions.

These three properties are discussed in detail and are also illustrated in accompanying drawings. A final section deals with multiplier photocells.

Internal Thread Comparator.—A leaflet describing the M.S.E. Internal Thread Comparator has been issued by Machine Shop Equipment, Ltd., 136-142, Victoria St., London, S.W.1. The comparator has a capacity of from ¼ in. to 8 ins. diameter and is supplied with three pairs of ball tips for measuring any threads from 4 to 20 per inch. The instrument has a 9 ins. beam carrying a sliding and a floating head, provided with reversible brackets fitted with interchangeable ball measuring tips. A fine adjustment clamp is fitted to the sliding head for setting the dial indicator to zero. Readings are taken by comparison after setting the instrument to zero by means of a composite master gauge built up in a slip gauge holder from Vee jaws and slip gauges.

Churchill Slideway Grinding Machines.—A 16-page nicely illustrated brochure issued by The Churchill Machine Tool Co. Ltd. Broadheath near Manchester, gives a detailed and well illustrated description of models VB and VBA Slideway Grinding machines for finishing all types of machine tool ways and slides. Experience has shown that ground surfaces are not only more accurate, and give better all-over contact than is possible with hand-scraped surfaces, but settle down immediately and wear much longer. The Slideway Grinder is intended to remove only sufficient metal to ensure the final accuracy in alignments.

BUSINESS NOTES.

Hobourn Aero Components Ltd., Coventry, whose factory suffered severely in the blitz, has been allocated the Temple Farm, Strood factory of Short Bros., Rochester, by the Board of Trade. Production of Hobourn Aero Components in their new Strood factory will commence during August.

Formation of National Gas Turbine Establishment.—Transfer of the main functions of Power Jets (Research and Development) Ltd. to a new organisation to be known as the National Gas Turbine Establishment has taken place (on July 1st).

The establishment, whose formation was announced in the House of Commons on 13th April by Mr. John Wilmot, Minister of Supply, will be responsible for research and development work on gas turbines and all their applications.

Power Jets (Research and Development) Ltd. will hand over their premises at Whetstone (near Leicester) and Pyestock (near Farnborough) to the new organisation. The company will, however, be kept in being to exploit Government-owned patents in the gas turbine field.

Dr. H. Roxbee-Cox, chairman and managing director of the company, has been appointed director of the new Establishment.

Messrs. E. H. Jones (Machine Tools) Ltd., announce that they have acquired a factory in Halifax, Yorkshire, where it is proposed to build an extensive range of high grade Machine Tools. The factory will be under the personal supervision of the Managing Director, Mr. E. J. M. Jones, assisted by a complete and efficient staff.

E.M.I. Supplies, Ltd. Manufacturers in Britain will be interested to learn that Electric & Musical Industries, Ltd., has launched a new Company—E.M.I. SUPPLIES, LTD., to specialise in buying on behalf of any firms who wish to avail themselves of a unique buying service.

The new company, with world-wide connections in many industries, offers to all the services of a team of expert buyers, supported by the full resources of one of our greatest industrial groups. The scope of the new company is very wide, covering raw materials, light and heavy engineering products, electrical products and components.

All manufacturers and commercial houses who are attracted by this new development are invited to communicate with the company with a view to preliminary discussions on their purchasing problems both Home and Export. The Head Office is at Blyth Road, Hayes, Middx. Telephone No: Southall 2468.

ORGANISATION IN A SMALL FIRM.

An example of good organisation with a full appreciation of the need to continue development may be seen in the works of The Hymatic Engineering Co. Ltd., Redditch.

At the beginning of the war this company, then called The Heywood Compressor Co. Ltd., made compressor sets for aeroplanes, which were adopted by the M.A.P. and fitted as standard equipment on all British service aircraft. Contracts of this magnitude encouraged the growth of the company and the Directors did not lose sight of the necessity to explore other avenues for the use of compressed air in the even more competitive field of civil applications.

The research Department is now spread over four sections :

(a) The Technical Information Bureau
(b) The Fundamental Research Section
(c) The Experimental Section
(d) The Unit Development Section.

The Technical Information Bureau collects all data and information relating to any relevant subject and carries out analyses of stress and investigates other technical problems. Typical problems submitted for analysis were the resistance to buckling of pneumatic aircraft-rams when subject to various acceleration loads, the preparation of a spring specification for ball valves, the calculations of optimum pressure in pneumatic systems on various criteria.

Work undertaken by the Fundamental Research Section is related to a definite project, the object being to obtain data not usually available. An example of the type of research carried out is the determination of the Callendar-Nicholson constants of heat transfer through a metal wall, in order to supply data for cooling problems. The Experimental Section carries out experimental work on existing units or components to gain new information not readily calculable, and the Unit Development Section carries out development work and prototype approval tests on new products.

Two additional sections have recently been added, i.e., Materials Investigation section and Process Development.

The equipment of the Department comprises ; dynamometers, compressed air test rigs, a refrigerator ranging down to -70 C., ovens for checking performance and reliability of products at extreme operating temperatures, vibration machines, ram testing machines, in addition to a variety of observation aids such as a stroboscope, vibrograph, anemometer. Other instruments necessary to qualitative control of the firm's products are also in use.

£3,000,000 Order for Road Rollers.—British industry is to help India to carry through her vast road-building programme. For this purpose manufacturing resources in this country, together with the facilities provided by Indian Ordnance factories, will be made available.

The Government of India has entered into commitments totalling about £3,000,000 with two leading British manufacturers.

The manufacture of steam rollers has been entrusted to Marshall's of Gainsborough, and that of Diesel rollers to Aveling-Barford of Grantham. Both firms have agreed to place at the disposal of the Ordnance factories all the technical data and information necessary for full co-operation. Assembly and tests will take place in India prior to delivery to the various provinces there.

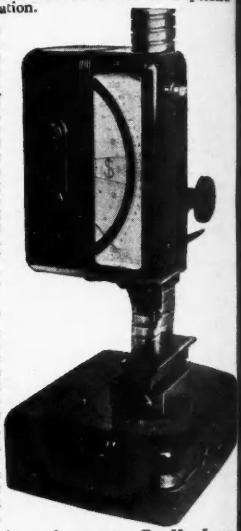
"The effects of this agreement are far-reaching," said Mr. G. Bryden, Managing Director of Marshall, Sons & Co. Ltd., leader of the mission. "The alleviation of famine conditions in India is seriously hampered by lack of roads. That country's road programme and the switch-over of ordnance factories to it, also supply a means of using India's huge man-power and her wartime industrial resources.

"It is," he concluded, "reassuring to know that while India's political destiny is still shaping, an agreement of this kind can be brought into being. It may provide a useful lesson for the future as a tangible sign of how the resources of two great countries can be used to their mutual benefit."

For British Leadership in Electronics.—Electric and Musical Industries Ltd., Hayes, Middlesex, pioneers in the development of Television and other electronic applications, has created an organisation to provide training over the whole sphere of electronic sciences for all types of students. This organisation—E.M.I. Institutes Ltd.—acquired the London Radio College to provide there technical training in television, radar, radio and associated techniques. Professor H. F. Trewman, M.A. (Cantab), M.I.E.E., M.I.Mech.E., has been appointed Principal of the new institute in which Sir Ernest Fisk, managing director of Electric and Musical Industries Ltd., takes keen personal interest.

NEW EQUIPMENT

New 3000 : 1 Comparator.—A mechanical comparator carrying an N.P.L. certificate of accuracy to 0.000004 in. (four millionths of an inch) is a new product of the Sigma Instrument Co. Ltd., and is the latest development in their range of vertical mechanical comparators. The operation is similar in principle, employing magnification in two stages through lever mechanism, but two important modifications of design are incorporated. Where as in the standard comparator, operation of the first lever depends on movement of an annular ring, the fulcrum of this lever on the new comparator comprises four cross springs, mounted in pairs at right angles to each other. An adjustable eccentric device is incorporated to permit adjustment of magnification.



A second feature is a magnetic counterpoise which provides constant anvil pressure over the entire range. This counterpoise comprises a magnet mounted over the top of the spring assembly. In principle, the operation depends simply on the fact that as the spring pressure increases, the air gap decreases and the magnetic pull on the spring assembly is increased correspondingly. Thus, as spring tension increases, the magnetic arrangement gives increased attraction to compensate for the increased spring pressure. A magnetic shunt is incorporated to permit adjustment.

The head is clamped rigidly on the column during operation. Use of a keyway and second clamping screw gives positive location in the radial plane while still permitting vertical adjustment. Full scale deflection is ± 0·001 in., the scale being provided with an anti-parallax mirror. Each main sub-division represents 0·0001 in. These sub-divisions are divided again, to give a scale calibrated in 0·00002 in. A metric scale is also incorporated.

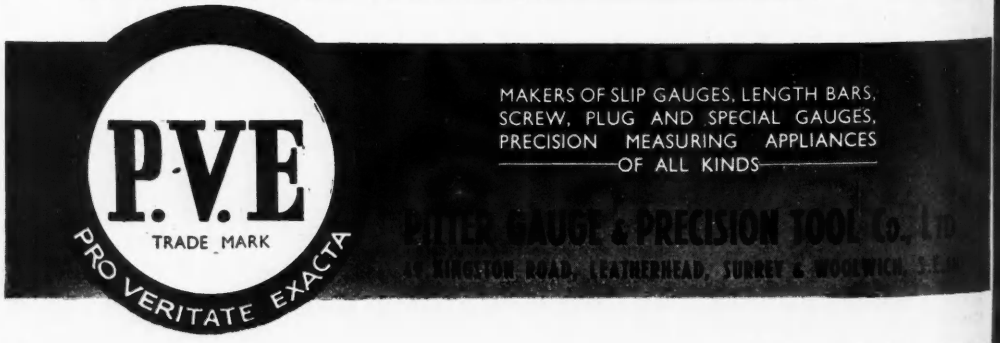
Distribution is through the sole agents, E. H. Jones (Machine Tools) Ltd., Edgware Road, The Hyde, London, N.W.9.

INTERNATIONAL TECHNICAL CONGRESS, PARIS, 1946.

An International Technical Congress is to be held in Paris from September 16th to 21st, 1946. The object being to emphasise the important part which must be played by engineers and other technicians in the period of post-war reconstruction, and to stress the necessity for technicians from different nations to collaborate. Papers for discussion are being contributed from many European countries and the United States of America, and include several from Great Britian.

The subjects cover a wide range and the method of presentation takes the form of reports on recent progress and developments in such fields as plastics, construction, aeronautics, power plants, and town-planning, as well as more abstract matters such as the position of the technician in the political structure.

The organising secretary for Great Britian is Mr. Robert Lowe, 82, Victoria Street, London, S.W.1.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